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LEVEL

ALTITUDE ALTIMETER FLIGHT TEST

AIR FORCE AVIONICS LABORATORY

Aerospace, Orlando Division

Florida 32805

1978

August 1977 – 30 September 1978

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The HAAFT program was conducted to obtain high altitude radar altimeter data that could be used in a feasibility assessment of High Altitude TERCOM (HATCOM). The HAAFT program involved collecting altimeter data over seven scenes with terrain altitude standard deviations ranging from 25 to 320 feet located in the vicinity of Edward AFB and Point Mugu, California. Two pulse and one FM/CW altimeters were operated simultaneously at nominal altitudes of 5, 20, 30, 45, and 65 kft, AGL. → next page

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The aircraft three-dimensional position was measured and provided by the AN/FPS-16 radar sets at Edwards AFB and Pt. Mugu. The tracking data were later merged with the data recorded in the aircraft and stored on computer tapes. An inertial navigator was included in the flight test equipment to provide aircraft attitude, velocity, and position data.

In addition to the normal altitude measurement data provided by the altimeters, the pulse return waveform for the pulse altimeters and the prediscriminator waveform for the FM/CW altimeter were processed to be recorded on television video cassette recorders.

FOREWORD

Martin Marietta Aerospace, Orlando, Florida, submits this final report to the Air Force Avionics Laboratory, AFAL/RWT-2, Wright-Patterson AFB, Ohio, 45433 in response to CDRL Data Item No. 4 of contract F33615-77-C-122, Project 1995, Task 07. This contract for the High Altitude Altimeter Flight Test (HAAFT) program was under the direction of Mr. Edward Hamilton and covers the period from 1 August 1977 to 30 September 1978.

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SECTION I

SUMMARY

Increasingly stringent accuracy requirements for aircraft navigation and for other future long range air-to-ground weapon systems have pushed current avionics technology to the limits. Recent efforts in terrain contour matching (TERCOM) indicate that TERCOM can satisfy these stringent accuracy requirements for low altitudes (< 5000 feet). High altitude TERCOM (HATCOM) is an attractive candidate for systems requiring accurate high altitude updates, but no data base existed to determine HATCOM performance. Therefore, the HAAFT was conducted to obtain the necessary data base required to validate analytical models, refine altimeter/terrain simulation models, and determine the feasibility of HATCOM.

The HAAFT program obtained radar altimeter data from three radar altimeters over seven scenes with varying terrain roughness characteristics at five flight altitudes. Three passes were made at each altitude for each scene, except for the lowest altitude (two passes due to recorder limitation), to obtain a statistically significant data base. When the combination of number of scenes, flight altitudes, and passes for each altitude and scene is considered, 110 actual passes were flown. The three radar altimeters were operating simultaneously, and the number of equivalent passes was 330. Since each scene was approximately 10 miles long, radar altimeter data were recorded for an equivalent of 3,300 miles. From these data, conclusions can be confidently made.

The three flight-tested radar altimeters represented existing state-of-the-art instruments originally designed for other applications and were supplied by the altimeter manufacturers for evaluation as HATCOM sensors. Stewart Warner Electronics supplied an AN/APN 203A, a pulsed altimeter designed for high-altitude operation. Honeywell, Incorporated supplied an HG7196 V1, a prototype of their new high-altitude pulsed altimeter. Kollsman Instruments supplied an AHV-70, a breadboard of a new FM/CW altimeter designed for 70,000 feet operation. The pulsed altimeters used different peak powers and pulse lengths, but both use leading edge detection of the return pulse. The FM/CW represented a very low transmitted power approach and used spectrum leading edge detection to accomplish the same effect as the pulse leading edge detection. These altimeters represent the range of radar altimetric approaches presently available and should provide insight into the effect of the various altimeter parameters on correlation performance. It should be noted that the altimeters and the technical support were provided to the program by the suppliers at no cost, and this support was a major factor in the success of the HAAFT program.

In evaluating correlation update systems, it is necessary to know precisely where the data were gathered. Therefore, when the flight tests were conducted, accurate ground track information was provided by ground tracking systems at the Air Force Flight Test Center (AFFTC) at Edwards Air Force Base and Pacific Missile Test Center (PMTC), Point Mugu. The groundtracking systems used a C-Band transponder mounted on the aircraft. Accurate time referenced was provided by an IRIG time code generator which was synchronized with WWV (the same time reference used by the groundtracking stations) prior to aircraft takeoff. In addition, a Litton LN-33 inertial navigation system was used to provide backup ground track data in the event that the ground station temporarily lost track. Figure 1 shows the airborne equipment signal and electrical interface and Figure 2 shows the flight hardware installed in the aircraft.

Except for voice annotation, all data recorded were in digital format. The measured altitude data and automatic gain control (AGC) voltages from the three altimeters, the position, velocity, and attitude data from the inertial navigation and the IRIG time reference were formatted to facilitate computer processing and were recorded on the Honeywell 5600C data recorder. In the laboratory, these data were merged with the ground track data and were recorded on digital computer tapes in EBCDIC format (Figures 3 and 4). These computer tapes were the primary output of the HAAFT program.

In addition to providing data to evaluate the correlation performance with the flight test altimeters, the HAAFT program also obtained data that could be used to investigate potential refinements in the altimeters. This was accomplished by a video recording system that was mechanized to record the return pulses of the pulse altimeters and the prediscriminator signal of the FM/CW altimeter. The most challenging portion of this task was the recording of the return waveform from the pulse altimeters, since the duration of the complete waveform was less than 2 microseconds. A circuit was designed to sample the waveform at 10 nanosecond intervals, digitize it into a 4 bit digital word and time base expand it to be recorded on a television video cassette recorder with a bandwidth capability of approximately 3 MHz. This was accomplished by storing the data in a random access memory (actually eight operating in parallel) and then clocking the data out at a rate slow enough to be compatible with the video cassette recorder bandwidth. These data were stored in digital format on the cassettes so that the noise associated with analog recording would not be introduced. Due to the amount of data to be recorded and the bandwidth limitation of the recorders, every other pulse was recorded, which resulted in 2500 pulses from each pulse altimeter being recorded each second. Evaluation of the FM/CM altimeter data required recording a continuous waveform. Since only one recording channel was available on the video recorder and the data from three altimeters were required, the data were multiplexed. The data from the FM/CW sensor were time base compressed (the reverse of the pulse recording technique) so that it could be recorded and yet leave time to record the data from the two pulse altimeters. During the data analysis, the FM/CW prediscriminator continuous waveform was reconstructed by time expanding the recorded waveform.

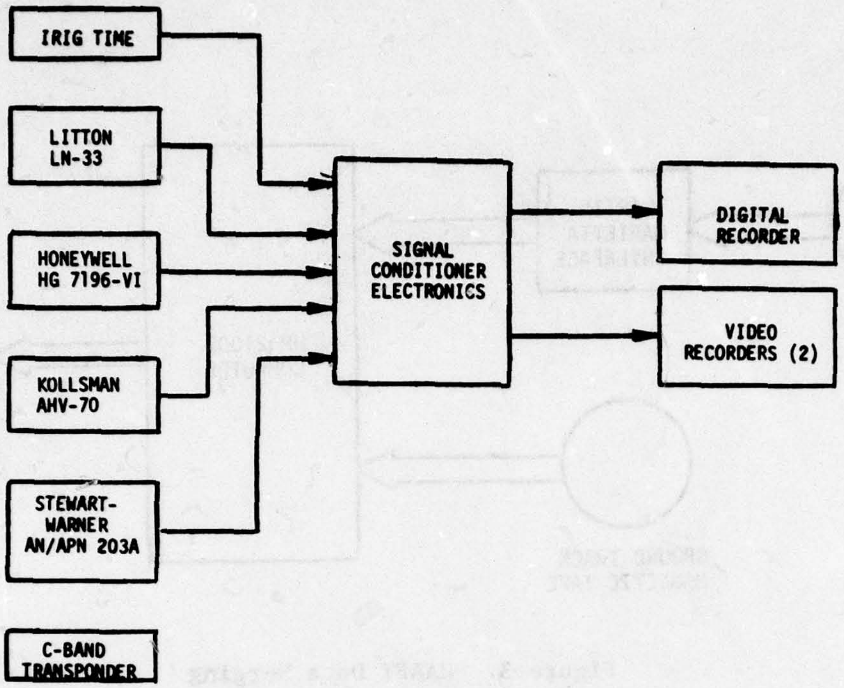


Figure 1. HAAFT Airborne Equipment Signal Interface

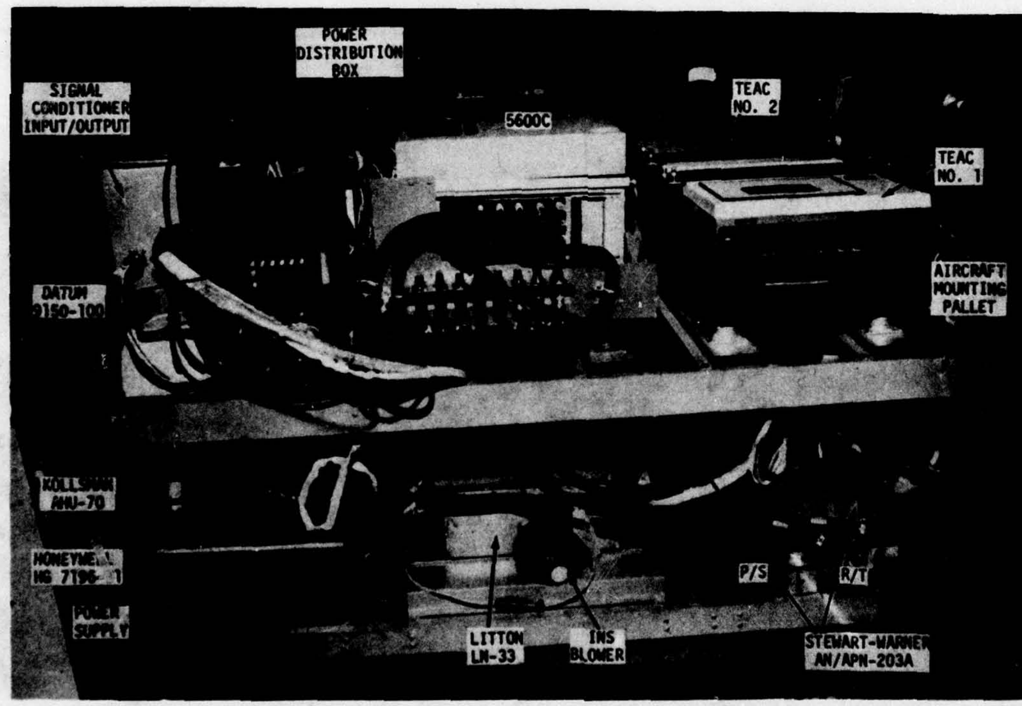


Figure 2. HAAFT Equipment/Pallet Installation

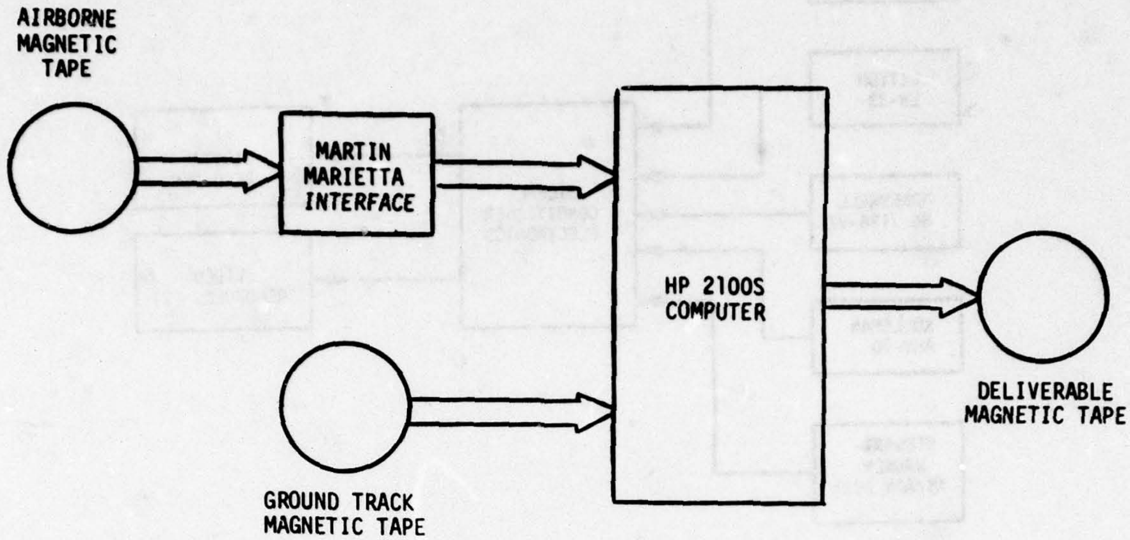


Figure 3. HAAFT Data Merging

Figure 4. HAAFT Computer Equipment

In addition to the video data recorded, the voice annotation and IRIG time on the data recorders were recorded on the voice channels of the video cassettes so that the waveform data could be related to the measured altitude and the ground track data. Figure 5 shows the technique used to record the data, and Figure 6 shows a typical reconstructed analog signal using the recorded digitized data. The characteristics of the terrain from which the data were obtained can be determined by comparing the ground track data with topographic charts or digitized terrain data from the Defense Mapping Agency Aerospace Center (DMAAC).

Duplicates of the recorded video cassettes, along with a schematic diagram of the circuit necessary to decode the digital waveforms, were provided as output of the HAAFT program.

The following paragraphs provide a more detailed discussion of the flight test hardware, preflight test results, the flight test operations, and the data format of the computer data tapes and video cassette recordings.

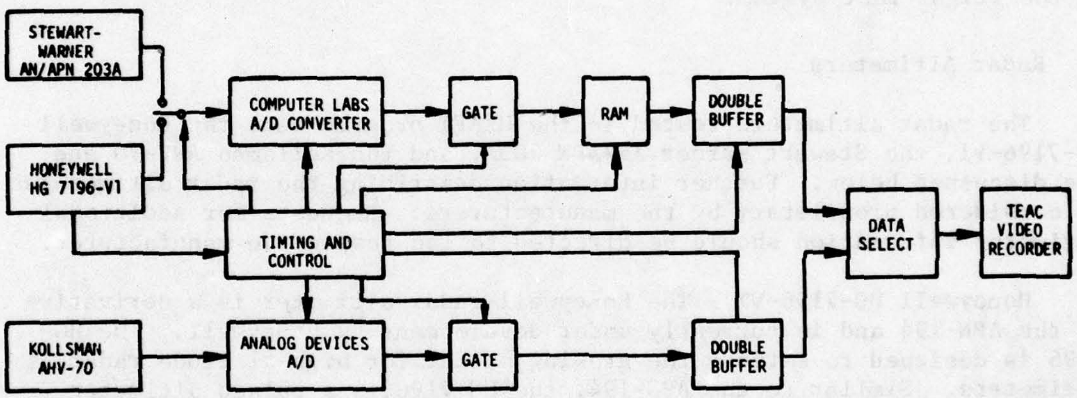
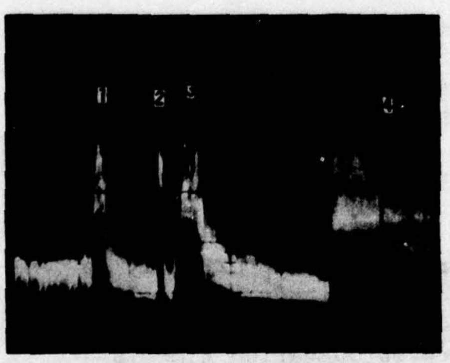


Figure 5. Simplified Block Diagram of the Video Processor and Recorder Interface



1. HONEYWELL VIDEO PULSE
2. INTER PULSE DECODER NOISE
3. STEWART-WARNER VIDEO PULSE
4. KOLLSMAN BEAT FREQUENCY

Figure 6. Oscilloscope Display of Recorded Waveforms

SECTION II

FLIGHT TEST HARDWARE

The primary elements of the flight test hardware were the radar altimeters since the motivation of the program was to obtain radar altimeter data. The remainder of the equipment was required to provide the necessary power conditioning, signal conditioning, recording, and ground track instrumentation. A functional block diagram of the airborne equipment is presented in Figure 7. Figure 8 shows the flight hardware installed on the pallet for mounting in the aircraft showing additional details of the I/O circuitry. The following paragraphs describe the hardware elements included in the flight test system.

1. Radar Altimeters

The radar altimeters tested in the HAAFT program were the Honeywell HG-7196-V1, the Stewart Warner AN/APN 203A, and the Kollsman AHV-70 and are discussed below. Further information describing the radar altimeters is considered proprietary by the manufacturers. Requests for additional altimeter information should be directed to the respective manufacturer.

Honeywell HG-7196-V1 - The Honeywell radar altimeter is a derivative of the APN-194 and is currently under development by Honeywell. The HG-7196 is designed to satisfy the growing market for high-altitude radar altimeters. Similar to the APN-194, the HG-7196 is a pulsed altimeter using conventional leading edge detection to measure the highest point in the antenna pattern. The significant characteristics of the HG-7196 are presented in Table I.

Stewart Warner AN/APN-203A - The Stewart Warner AN/APN-203A is designed for aircraft application and has been used in several previous programs. The AN/APN-203A is also a pulsed altimeter with more peak transmitted power and shorter pulse length than the HG-7196. The AN/APN-203A also uses leading edge detection to sense the highest point in the antenna pattern. The AN/APN-203A characteristics are presented in Table II.

Kollsman AHV-70 - The Kollsman AHV-70 provided an opportunity to evaluate a completely different approach to high-altitude radar altimetry. This concept uses very low transmitted power. The transmitter frequency is linearly modulated, and the energy propagation time is sensed by frequency discrimination techniques. Advocates of FM/CW

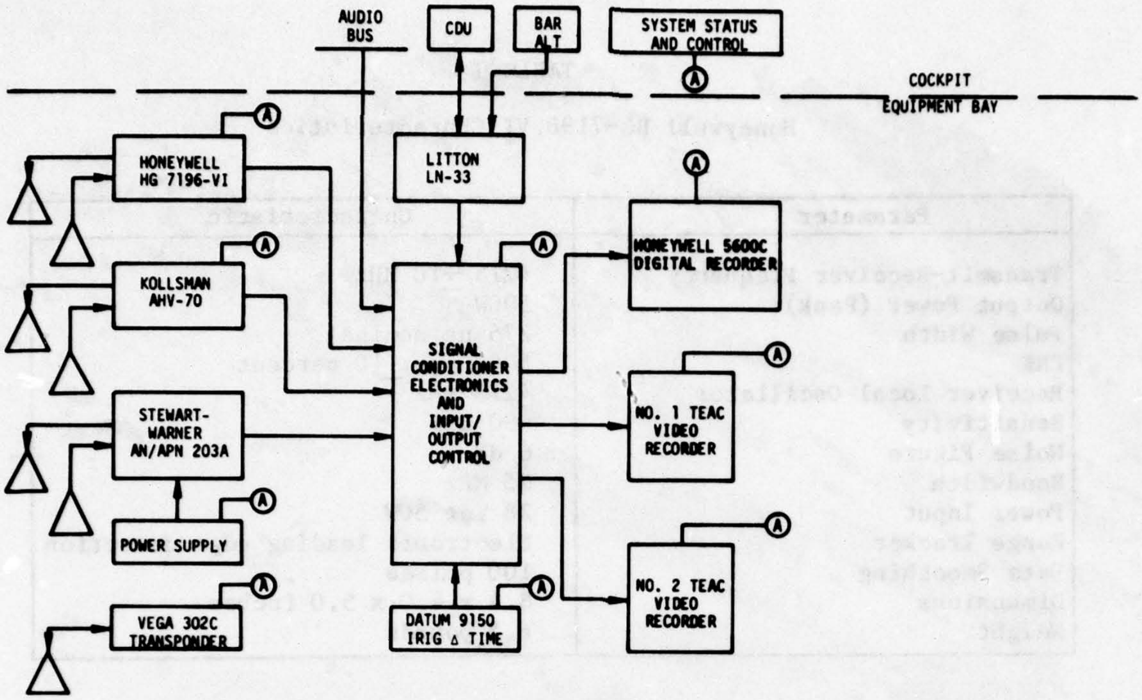


Figure 7. HAAFT Flight System Block Diagram

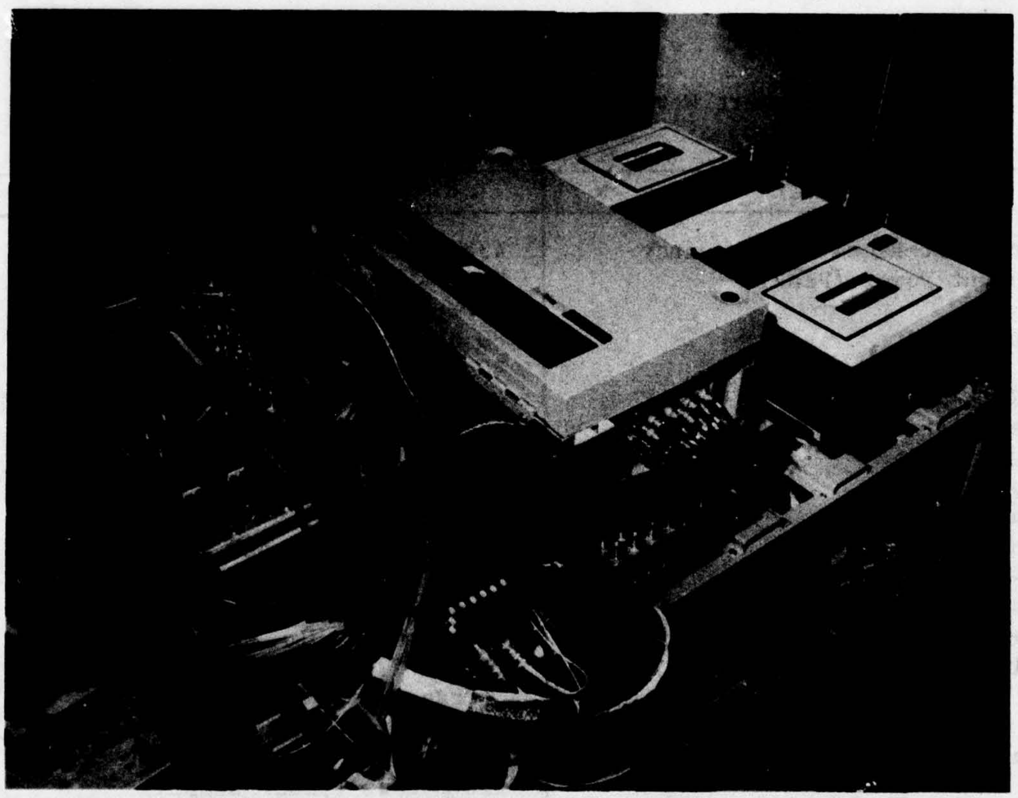


Figure 8. HAAFT System Installation

TABLE I

Honeywell HG-7196 VI Characteristics

Parameter	Characteristic
Transmit-Receiver Frequency	4215 $\pm$10 MHz
Output Power (Peak)	500W
Pulse Width	275 ns nominal
PRF	5000 pps $\pm$10 percent
Receiver Local Oscillator	4215 MHz
Sensitivity	-90 dBm
Noise Figure	6 dB
Bandwidth	25 MHz
Power Input	28 Vdc 50W
Range Tracker	Electronic leading edge detection
Data Smoothing	100 pulses
Dimensions	8.4 x 4.0 x 5.0 inches
Weight	6.5 pounds

TABLE II

Stewart Warner AN/APN 203A Characteristics

Parameter	Characteristic
Transmit-Receiver Frequency	4385 $\pm$10 MHz nominal
Output Power (Peak)	2 kW above 2000 feet 800W below 2000 feet
Pulse Width	80 ns nominal 40 ns below 2000 feet
PRF	4916 pps
Receiver Local Oscillator	4445 MHz nominal
Sensitivity	-78 dBm
Noise Figure	12 dB including IF
Bandwidth	12 MHz nominal
Power Input	108 to 120 Vac, 400 $\pm$20 Hz, 1A 21 to 29 Vdc, 1A
Range Tracker	Electromechanical resolver
Data Smoothing	16 pulses
Dimensions	26.8 x 7.5 x 6.0 inches (transmitter-receiver) 8 x 4.1 x 4.2 inches (power supply)
Weight	24.3 pounds (transmitter-receiver) 4.8 pounds (power supply)

concepts maintain that the frequency discrimination techniques are easier to mechanize than the timing required by the pulsed systems.

The transmitted frequency is varied over 125 MHz in a linear ramp format. The frequencies of the return waveform are compared with the transmitted frequency, and the altitude measurement is based on the minimum difference frequency (a technique called spectrum leading edge detection by Kollsman). This is analogous to the leading edge detection of the pulsed altimeters since the minimum difference frequency corresponds to the minimum slant range or nearest point on the terrain. In the actual mechanization, the minimum difference frequency is held essentially constant by adjusting the rate of change (ramp slope) of the transmitted frequency. Altitude data are then derived from the time for the transmitted frequency to traverse the 125 MHz range. Since the information is contained in a very narrow frequency band (after mixing the return waveform with the transmitted waveform), a narrow intermediate frequency bandwidth can be used with an associated increase in receiver sensitivity and attendant low required transmitter power. The AHV-70 characteristics are summarized in Table III.

TABLE III

Kollsman: AHV-70 Characteristics

Parameters	Characteristic
Transmit-Receiver Frequency	4300 MHz
Swept Bandwidth	125 MHz
Output Power	0.2W
Modulation	FM-CW
Sensitivity	-110 dBm
IF Bandwidth	10 kHz
Power Input	115 Vac 400 Hz, 60W
Dimensions	13 x 10 x 8 inches
Weight	21 pounds

1.1 Simultaneous Operation

All three altimeters were operated simultaneously to minimize the required amount of flight time and obtain data from identical terrain from the three radar altimeters. Interaction between the altimeters was reduced to an acceptable level by operating the pulsed altimeters on opposite edges of the radar altimeter band (4200 to 4400 MHz), and the FM/CW altimeter was operated with a center frequency at 4300 MHz. This frequency separation, along with the isolation due to the antennas (>80 dB) reduced the interaction to a point that no mutual interference was

noted during the ground tests or during the flight tests. A more detailed discussion of the ground tests and results of these tests are presented in section 3.

1.2 Antennas

Separate transmit and receive antennas were used for each altimeter and were located at opposite ends of the lower hatch to maximize isolation between the transmit and receive antennas for a given altimeter. Also, since all the transmit antennas were on one end of the hatch and the receive antennas were on the other end, this maximized the isolation between altimeters. Conventional sheet metal horns were used for simplicity of design and fabrication.

Care was also taken to design the antennas to provide nearly identical gain and pattern shape for all antennas so that no altimeter would have a gain or pattern advantage over another. Figures 9 and 10 present the antenna patterns for the center horns and side horns, respectively. These patterns indicate that both types of antennas have nearly identical gains of approximately 18 dBi and with 3 dB beamwidths of 18 degrees.

2. Inertial Navigation System

Litton Industries provided an LN-33 inertial navigation system for use in the flight test to provide ground truth backup to the ground tracking system, as well as providing aircraft attitude information (also at no cost to the program). The LN-33 was originally designed for aircraft application, but is, along with its derivatives, being used in missile systems. The LN-33 uses the Litton P-1000, a four gimballed platform, operated in the local level mode. The navigation equations are mechanized in an LC-4516 digital computer. The LN-33 is a 1 nmi/hr class navigator, although the flight test data indicated that the flight unit was performing at a level considerably better than the 1 nmi/hr. The detailed characteristics are considered proprietary by Litton and are available from Litton.

3. IRIG Time Code Generator

A DATUM, Inc. Model 9150-100 International Range Instrumentation Group (IRIG) time code generator was used in the flight test equipment to provide the time reference. The Model 9150-100 was configured with IRIG code A. This device uses a temperature compensated crystal oscillator to produce a time stability of one part in 10^9 (specification). During preflight operations, the time code generator was synchronized with WWV to within 100 microseconds. Since the AFFTC and PMTC ranges use WWV as their time reference, synchronization with the same time reference and taking into account the propogation differences provided assurance that the airborne data and ground track data could be merged within the 1 millisecond accuracy required by the statement of work. The characteristics of the DATUM time code generator are summarized in Table IV.

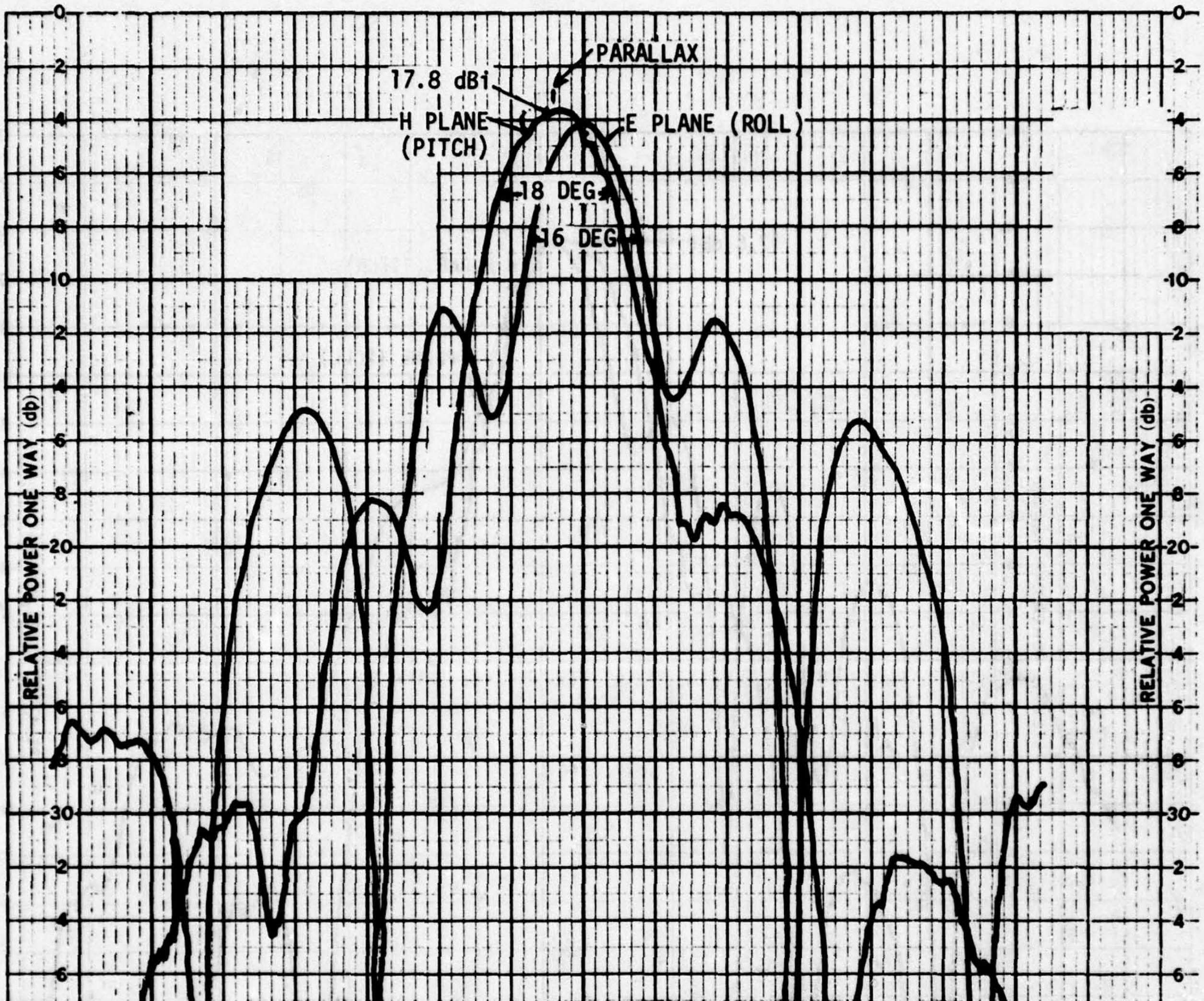


Figure 9. Antenna Pattern for Center Horn

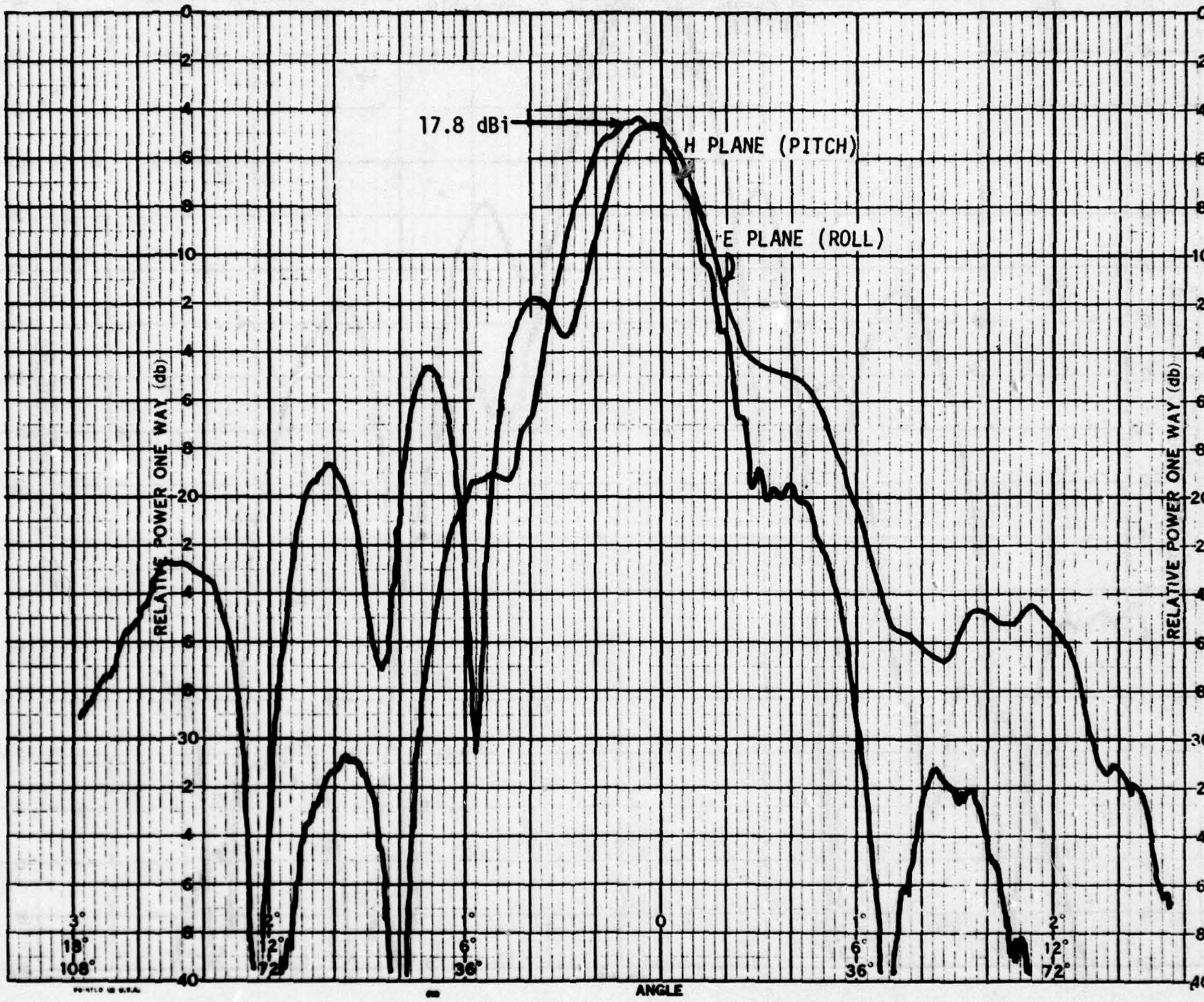


Figure 10. Antenna Pattern for Side Horn

TABLE IV

9150-100 IRIG Generator Characteristics

Size	7.6 x 4.9 x 12.6 inches (1/2 ATR)
Weight	25 pounds
Power	+28 Vdc ± 6 Vdc, 20W
Code	IRIG A
Operating temperature	0 to +50°C
Stability	1×10^{-9}
Synchronization	External (WWV) 1 pps

4. Recorders

Three recorders were used during the flight test program. A 14 track Honeywell 5600C, 1 inch tape machine configured for digital recording was used to record the digital output data from the altimeters and the inertial navigator. Two TEAC V-1000 AB video cassette recorders were used to record the return waveforms from the altimeters. The IRIG time data were recorded on all recorders so that these data could be compared at the same time and be synchronized with the ground track data during the data merging process.

Honeywell 5600C - The Honeywell 5600C configured with digital record cards was used without modification. The channel assignments are shown in Table V. This machine is a 14 channel data recorder with two edge tracks yielding a total of 16 available channels, although the edge tracks are lower in quality than the other 14 channels. Redundant channels were used on the critical data for improved recording reliability.

To assure adequate recording time capability, a recording speed of 3 3/4 in/s was used for the initial flights. However, some minor problems were encountered in transferring data into the computer due to dynamic skew. The dynamic skew caused relative shifting of the data and the clock signals. With the exception of a portion of AGC data, the data were recovered, and no flights had to be repeated. During the last two flights, the tape speed was increased to 7 1/2 in/s, and the dynamic skew problem was essentially eliminated.

TEAC V-1000 AB - Two TEAC V-1000 AB video cassette recorders provided a total of 1 hour of recording time. Each cassette has 30 minutes of record time available, and the recorders are configured so that the second recorder started when the first finished a tape. This provided the full hour of recording capability required by the longest mission. The V-1000 ABs have a video channel and two voice channels. The return waveforms were multiplexed and recorded on the video channel. The voice annotation that was recorded on the data recorder was also recorded on one of the V-1000 voice channels. The IRIG time data were recorded on

TABLE V

Channel Assignments

Recorder	3 3/4 IPS Tape Track	Measurement	Signal Format	Signal Range	Scale Factor	Remarks	7 1/2 IPS Tape Track
5600C	Edge "A"	Voice	Analog	N/A	N/A	Flight Annotation	Edge "A"
	1	IRIG Time A	Digital	Continuous	1000 pps	Flight Time Base	1
	2	Altimeter No. 1	24 Bit Serial Digital	0 to 131,070 ft	LSB = 2 ft	Performance Data	2
	3	Altimeter No. 1	24 Bit Serial Digital	0 to 131,070 ft	LSB = 2 ft	Redundant Data	3
	4	Altimeter No. 2	20 Bit Serial Digital	0 5o 131,070 ft	LSB = 2 ft	Performance Data	4
	5	Altimeter No. 2	20 Bit Serial Digital	0 to 131,070 ft	LSB = 2 ft	Redundant Data	5
	6	Altimeter No. 3	22 Bit Serial Digital	0 to 98,302 ft	LSB = 1.5 ft	Performance Data	6
	11	Altimeter No. 3	22 Bit Serial Digital	0 to 98,302 ft	LSB = 1.5 ft	Redundant Data	11
	9	Inertial Nav System	224 Bit Serial Digital				10
			16 Bit Address	N/A	N/A	Buffer Address	
			32 Bit X	0 ± 180 deg	LSB = 6 sec	Double Precision	
			32 Bit Y	0 ± 180 deg	LSB = 6 sec	Double Precision	
			16 Bit Inertial Ht.	0 to 262,140 ft	LSB = 4 ft	Single Precision	
			16 Bit V_N	0 ± 2048 ft/s	LSB = 0.125 ft/s	North Velocity	
			16 Bit V_E	0 ± 2048 ft/s	LSB = 0.125 ft/s	East Velocity	
			16 Bit V_Z	0 ± 2048 ft/s	LSB = 0.125 ft/s	Vertical Velocity	
			16 Bit θ (+ CCW)	± 180 deg	LSB = 0.33 min	Usable Data Limit	
			16 Bit ϕ (+CCW)	± 180 deg	LSB = 0.33 min	is 1.68 min	
			16 Bit Ψ (+CW)	± 180 deg	LSB = 0.33 min		
			16 Bit Baro Alt.	0 to 262,140 ft	LSB = 4 ft	Aircraft Altimeter	
			16 Bit Nav Time	Continuous	LSB = 1 sec	INS Nav Time	
	10	Inertial Nav System	Same as Track #9			Redundant Data	14
	13	Altimeter #1 AGC	8 Bit Serial	0.8905 to -2.115	LSB = 0.510 VDC	Sensitivity Data	13
	14	Altimeter #2 AGC	8 Bit Serial	6.365 to 8.44	LSB = 6.635 VDC	Sensitivity Data	12
	12	Altimeter #3 Waveform	8 Bit Serial	0.152 to 1.16	2^4B = 0.152 VPP	Sensitivity Data	9
	7	Data Clock	Digital	Continuous	2.25 Khz	Data Reference	7
	8	Data Clock	Digital	Continuous	2.25 Khz	Data Reference	8
	Edge "B"	IRIG Time A	Digital	Continuous	1000 PPS	Flight Time Base	Edge "B"
TEAC V-1000AB	Audio 1	Voice	Analog	N/A	N/A	Flight Annotation	
	Audio 2	IRIG Time A	10 kHz	Continuous	1000 PPS	Flight Time Base	
	Video	Return Backscatter	Multiplexed Digital	3.25 MHz B/W	50:1		
		Leading Edge Pulse #1 and #2 and Pre "D" BFO Waveform			Time Expansion		

the other voice channel to facilitate comparison with the other recorded data. The general characteristics of the TEAC V-1000 AB are:

1 Weight - 30 pounds
2 Dimensions - 6.8 x 14 x 13 inches
3 Power - 84 watts at +28 Vdc.

5. Signal Conditioning Circuits

The output signals from each sensor were primarily designed for display on an indicator and not for recording and eventual processing by a computer. Therefore, signal processing circuits were designed to provide the interface between the sensors (altimeters, INS, and time code generator) and the digital data recorder and the interface between the altimeters and the video recorders.

5.1 Data Recorder Interface

The sensor signal conditioner block diagram (Figure 11) identifies the interface between the flight instruments and the Honeywell tape recorder. Since the sensor internal operations are independent and unsynchronized and data formats are different (Table VI), each unit had an interface and buffer memory assigned to it. For each instrument, this interface unit consists of an impedance and level translation circuit to reach transistor transistor logic (TTL) levels for storing in a RAM. In addition, the AHV-70 altimeter output data were in RZ format as indicated in Table VI, which required clocking each digital bit to reconstruct the digital word. From these RAM buffer memories the data are output with a leading four-bit code [1111] with a zero between each three-bit data word as shown in Figure 11. This permits identification of the data word by the read circuitry, which in turn formats the data for the computer interface. By this method, the recording process was accomplished without loss of integrity.

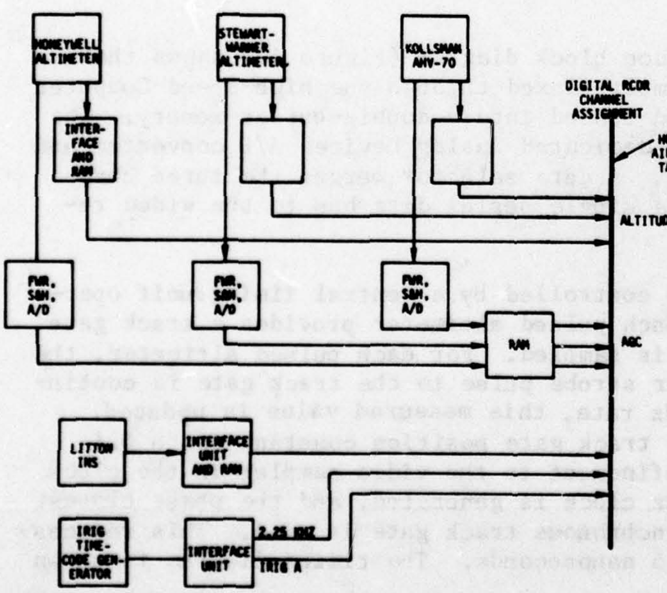


Figure 11. Sensor/Data Recorder Interface

NOTE: FWR, S&H, A/D - FULL WAVE RECTIFIER, SAMPLE AND HOLD, ANALOG-TO-DIGITAL

TABLE VI

Sensor Data Characteristics

Instrument	Format	Clock Rate	Control Mode
Honeywell 7196	24 Bit, Serial, NRZ	100 kHz	External
Stewart Warner APN 203	20 Bit, Serial, NRZ	7 kHz, 35 kHz (25 kHz)	External
AHV-70	22 Bit, Serial, RZ	266 kHz	Internal
Litton, INS LN33	One 16 bit address word Thirteen 16 bit data words	216 kHz Two-phase	Internal
Datum Time Code Generator	IRIG time A 1 MHz square wave 100 kHz square wave 10 Hz square wave		

In addition to the measured altitude data, the AGC level signals were obtained from the altimeters, digitized, and recorded. However, since the AHV-70 does not use AGC, the prediscriminator waveform was rectified, filtered, and then digitized for recording in lieu of the AGC signal. The digitized AGC signals from the pulse altimeters and the prediscriminator signal level data were stored in a buffer memory (RAM) prior to formatting for recording as indicated in Figure 11.

5.2 Video Recorder Interface

The video recorder interface block diagram (Figure 12) shows that the two pulsed altimeters are multiplexed through one high-speed Computer Labs MOD 4100 A/D converter and loaded into a double-buffer memory. The Kollsman FM-CW altimeter has a dedicated Analog Devices A/D converter and is then loaded into its memory. A data selector merges the three channels of data from memory onto a single serial data bus to the video recorder.

The sampling processor is controlled by a central timing unit operating from a 100 MHz clock. Each pulsed altimeter provides a track gate during which the video signal is sampled. For each pulsed altimeter, the time delay from its transmitter strobe pulse to the track gate is continuously measured and, at a 10 Hz rate, this measured value is updated. This effectively maintains the track gate position constant for a 0.1 second interval. A further refinement to the video sampler is the clock selection. A two-phase 100 MHz clock is generated, and the phase closest to the leading edge of the asynchronous track gate is used. This reduces the timing uncertainty to $\pm$ 2.5 nanoseconds. The timing diagram is shown

in Figure 13. In order not to exceed the recording bandwidth of the video recorders, i.e., 3.25 MHz, each pulsed altimeter is sampled at approximately 2500 Hz (shown in Figure 14). This results in a time-base expansion of 64 to 1, whereas the Kollsman altimeter has an equivalent timebase compression of 3.75 to 1.

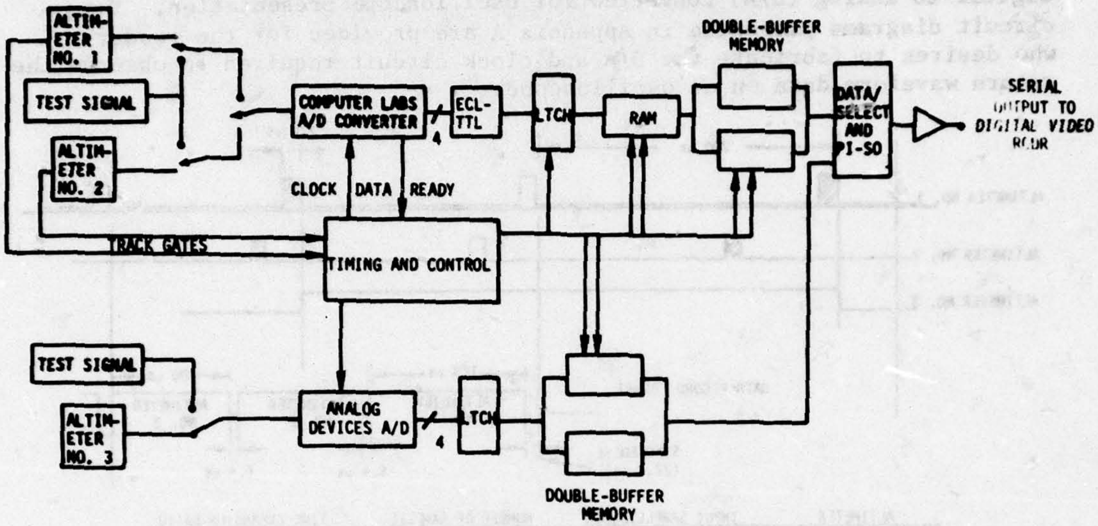


Figure 12. Video Recorder Interface Block Diagram

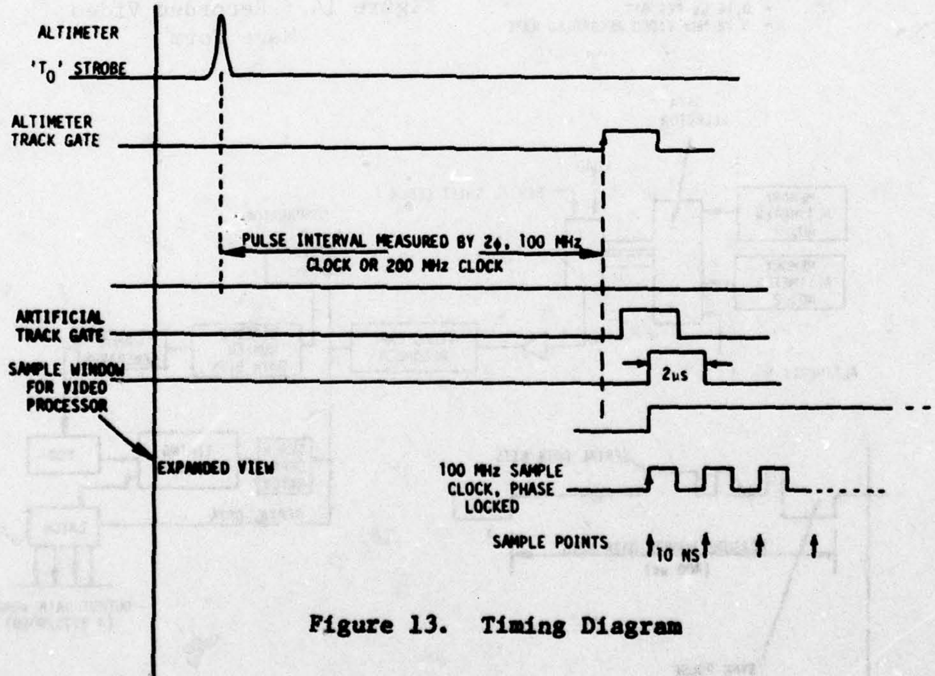
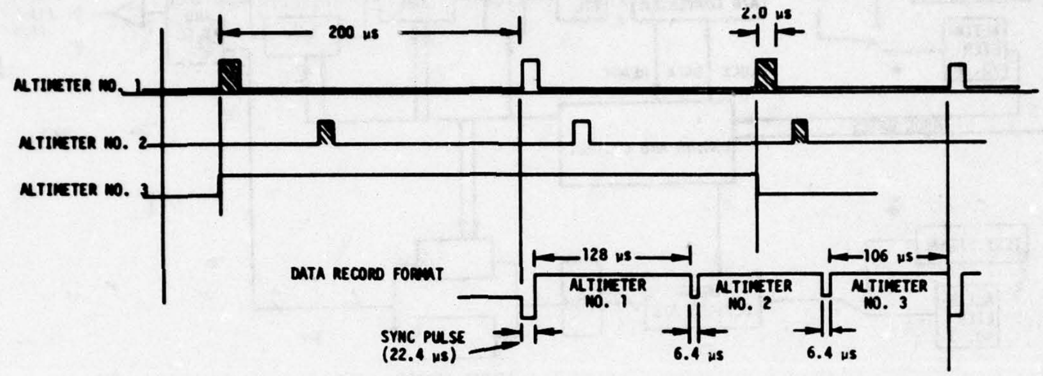


Figure 13. Timing Diagram

The three channels on the TEAC recorder are dedicated to video, audio, and IRIG, and hence a video data clock is not recorded. This requires that a clock be generated by the read electronics as shown in Figure 15. A voltage-controlled oscillator (VCO) is driven by the error signal derived from the measured clock, which is updated each synch pulse. The serial data from the tape is clocked into a 4-bit latch, and digital-to-analog (D/A) converted for oscilloscope presentation. The circuit diagrams presented in Appendix A are provided for the reader who desires to fabricate the D/A and clock circuit required to observe the return waveform data on an oscilloscope.



ALTIMETER	INPUT SAMPLE CLOCK	NUMBER OF SAMPLES	TIME EXPANSION RATIO
HONEYWELL	100 MHz	200	64 TO 1
STEWART-WARNER	100 MHz	200	64 TO 1
AHV-70	400 MHz	160	1 TO 3.75

OUTPUT DATA RATE → 0.64 μs PER WORD
= 0.16 μs PER BIT
= 3.12 MHz VIDEO RECORDING RATE

Figure 14. Recorded Video Wave Form

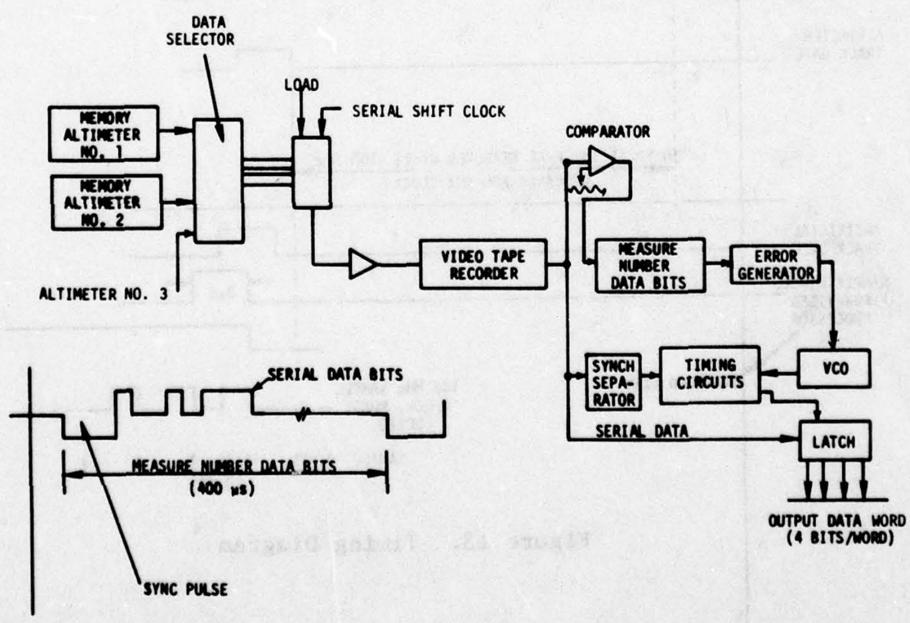


Figure 15. Video Data Record (Write) and Replay (Read) Technique

SECTION III

SYSTEM INTEGRATION AND GROUND TESTS

Following delivery to Martin Marietta, the radar altimeters were tested to evaluate the sensors against the expected performance.

Initially, a coaxial delay line with a length that would give an apparent altitude of 5000 feet was used to determine whether the altimeters were functioning. All altimeters indicated the proper altitude. An attenuator was then introduced to determine the amount of loop attenuation necessary to cause the altimeters to lose track. The HG-7196 required 136 dB of attenuation, the AN/APN-203A required 139 dB, and the AHV-70 required 132 dB to break lock. This test is somewhat qualitative in that using the delay line is analogous to radiating inside a sphere (all return energy occurs at the same time). This causes the return pulse shape to be essentially the same as that transmitted. Return from actual terrain will have a slower rise on the leading edge and may influence this measurement. Also, any changes in receiver gains or filter characteristics as a function of altitude would influence the results at maximum altitude since for these tests the altimeters would function as they would at 5000 feet altitude.

The pulsewidths of the pulsed altimeters were measured and found to be 200 nanoseconds for the HG-7196 and 80 nanoseconds for the AN/APN 203A. The expected pulse lengths were 275 nanoseconds for the HG-7196 and 80 nanoseconds for the AN/APN 203A. The shorter pulse length than expected for the Honeywell sensor was not considered a serious problem. The AHV-70 had continuous output as expected.

The transmitted power was measured and found to be 56 dBm peak (0.4 kW) for the HG-7196, 65 dBm peak (3 kW) for the AN/APN-203A, and 22 dBm continuous (0.16W) for the AHV-70. The HG-7196 was expected to have 500W peak (test unit was low); the AN/APN-203A was expected to have 2000W peak (test unit was higher); and 0.2W continuous was expected from the AHV-70 (test unit was low). These differences were noted and discussed with the suppliers and, since the antenna gains were approximately 8 dB higher (one way) than the antennas that would normally be used with altimeters, there was no concern about the lower than expected output power (~1 dB) for the HG-7196 and AHV-70.

Sensitivity measurements were conducted with the pulse altimeters by using a signal generator with a variable time delay. The time delay was varied over a range to simulate altitude variations of 5,000 to 70,000 feet. This was accomplished by triggering the time delay of the signal generator from the transmitted pulse. The units were first warmed up to

simulate actual flight operations. The HG-7196 sensitivity varied from -86 to -88 dBm over the altitude range. The AN/APN 203A varied from -81 to -84 dBm over the altitude range. The HG-7196 was found to have 2 to 4 dB less sensitivity than expected (-90dBm), and the AN/APN 203A had 1 to 4 dB more sensitivity than expected (-80 dBm). Neither was considered to be a serious deviation from the specification.

No technique was found to directly measure the sensitivity of the AHV-70 at altitudes above 5000 feet (delay line length). However, if one considers the transmitted power of 22 dBm and the loop loss of 132 dB required to make the AHV-70 lose track, a receiver sensitivity of -110 dBm at 5000 feet altitude results.

The question of mutual interference during simultaneous operation was examined by simulated isolation and later by connecting the altimeters to antennas in a sheet metal mockup of the hatch. The antennas were then pointed toward the sky, and the altimeters were turned on. Since there was no return available, all three altimeters continued searching - the condition where they would be most sensitive to interference. No mutual interaction or mutual interference was noted. (Later examination of flight data also showed no interaction between the altimeters.)

The LN-33 inertial navigator was tested by applying power on the bench, leveling and azimuth aligning, and then navigating for 6 to 8 hours on the bench. This test was repeated several times, and the results indicated that the device was operating with 0.25 to 0.3 nmi/hr drift, which is well within specified performance.

The interface circuitry was evaluated by simply operating the sensors with the delay line or signal generator on the bench and then examining the data that were recorded.

Each altimeter had minor malfunctions during the ground tests and was quickly repaired by the suppliers. The LN-33 operated at Martin Marietta for 6 to 8 hours on the bench and then failed. It was returned to Litton for repair four times. Litton repaired and operated it for many hours with no problems each time before returning it to Orlando. The last time that the LN-33 was returned to Litton, it failed at their facility. The problem was traced to a temperature sensitive component in the computer. Apparently, the environment at Martin Marietta was slightly warmer than the environment at Litton, which initiated the failure mode. After replacing the computer component, no further problems were experienced with the LN-33. No malfunction of any of the flight hardware was experienced during the actual flight tests.

1. Environmental Test

Prior to integrating the equipment with the aircraft, environmental tests were conducted to assure that the equipment would operate in the environment of the aircraft equipment bay. The equipment was mounted on the flight pallet and operated in the altitude chamber (Figure 16). The

altitude chamber was evacuated to simulate 35,000 feet pressure altitude (the test environment specified by the aircraft contractor). The concern was that the reduced air density might cause overheat problems. The maximum thermal time constant of the equipment was 1 hour. Therefore, the test was conducted for 3.5 hours. The equipment stabilized at temperatures well within operating limits and the test was terminated. Table VII shows the time/temperature history of the temperature/altitude test.

The test aircraft vibration and shock environments were specified and demonstrated as shown in Table VIII. These environments are relatively benign and, with the exception of power supplies and the interface or signal processing circuits designed at Martin Marietta, the flight hardware is flight qualified to more stringent environments. Therefore, the power supplies and signal processing circuits were installed on the shaker table in the Dynamics Laboratory. The dynamic environment equipment at Martin Marietta is not designed to function at the low levels specified. Therefore, the equipment was turned on and operated while experiencing the dynamic environments of Table VIII. No anomalies were noted in the power supplies or signal processing equipment during the dynamics environment tests.

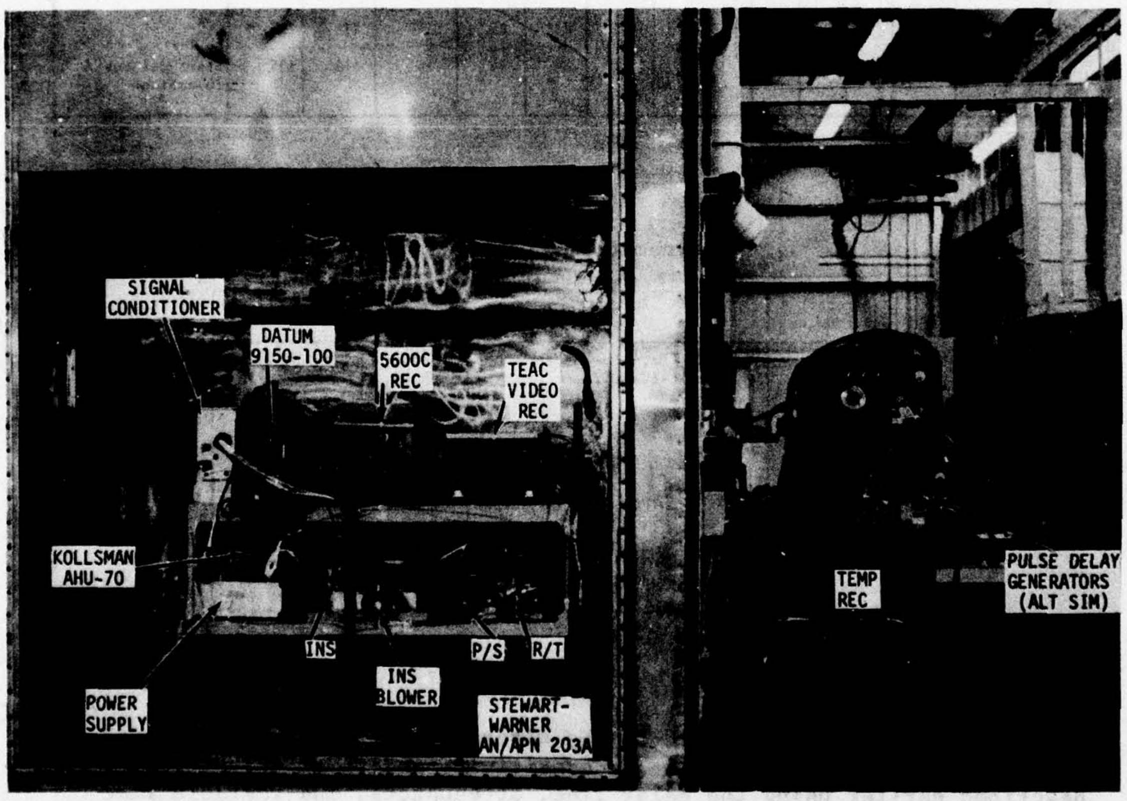


Figure 16. Altitude Chamber Installation

TABLE VII

Temperature/Altitude Test History

Test °F Time	5600C	INS	INS Fan	A/D	Signal Condition	DATUM 9150	TEAC No. 1	TEAC No. 2	HG-7196	AHV-70	Power Supply	Remarks
N/A	76	82	180	78	76	76	68	68	101	103	86	Initial reading after pretest
0:00:00	80	102	184	82	80	81	72	72	103	106	97	Start ascent to 35,000 MSL
0:15:00	85	122	140	88	86	84	74	74	102	104	108	
0:30:00	91	134	139	97	94	90	78	78	104	106	117	
0:45:00	94	142	140	102	98	94	80	79	109	108	124	
1:00:00	99	147	138	103	97	96	79	79	110	108	127	
1:15:00	101	149	138	104	98	98	80	80	112	109	130	
1:30:00	103	151	140	106	100	100	81	82	112*	110*	132	*Power off check malfunction
1:45:00	105	153	142	108	102	102	82	84	106	107	134	
2:00:00	108	155	142	109	102	103	83	85	102*	104*	135	*Power on
2:15:00	108	155	140	109	100	103	81	84	106	106	134	
2:30:00	107	155	140	108	100	102	81	84	108	106	133	
2:45:00	106	154	140	107	99	102	80	84	112	109	133	
3:00:00	107	154	140	107	99	102	80	84	112	110	133	
3:15:00	106	154	140	106	100	102	81	85	114	111	133	
3:30:00	106	154	140	106	100	102	80	84	114	111	133	Start descent to ambient

TABLE VIII

Dynamic Environments

Aircraft Environment	Specified Level		Preflight Certification Level
Vibration	95 to 100 Hz, sine, 0.001 inch DA, vertical axis		95 to 100 Hz, sine, 0.01 inch DA, three mutually orthogonal axes, 30 minutes/axis
Shock	Direction	Load (g)	
	Down	6.0	Requirement satisfied by loads analysis submitted with Preliminary Hazard Analysis Report, OR 14,816, CDRL sequence 10 to AFAL, WPAFB, Ohio
	Up	2.5	
	Side	2.5	
	Aft	2.5	
	Forward(crash load)	8.0	

2. Preflight Tests

The equipment was shipped to the aircraft contractor facility and integrated with the aircraft. The sensitivity and power output tests described earlier using the delay line, attenuators, and variable time delay signal generator were repeated after integration with the aircraft to assure that the sensors were all operating properly. (These tests were also repeated before and after each flight to guarantee that the equipment had not failed.)

SECTION IV

FLIGHT TEST OPERATIONS

1. Test Scenes

Data were obtained from a total of seven scenes during the HAAFT program. Five of the scenes were located within the restricted area of the AFFTC, Edwards AFB, Ca. Two scenes were located in the Thousand Oaks, Ca., vicinity and were under joint operational control of the PMTC, Pt. Mugu, Ca., and the Los Angeles Air Traffic Control Center.

The five scenes at AFFTC (Figure 17) were selected as the original flight areas for all data gathering operations with terrain height standard deviations (σ_T) of 24 feet, 52 feet, 109 feet, 212 feet, and 304 feet. However, due to DMAAC prior scheduled workload, digitization of all scenes could not be accomplished in time for use in the data analysis study contract schedule (not part of the HAAFT program). Direction was received in January 1978, prior to the start of flight operations, to select two scenes from an existing digitized area in the Pt. Mugu, Ca., area (DMAAC designated area E-2). The two scenes selected in the E-2 area (Figure 18) have standard deviations of 320 and 175 feet, respectively, and were used to replace scenes 2 and 3 at AFFTC. However, when the flight tracks were considered, deletion of the two AFFTC scenes did not result in any flight time savings. Therefore, all five of the AFFTC scenes were overflown and data were obtained on all scenes. Prior to the actual flights, it was not planned to obtain video (return waveform) data over the replaced scenes due to recording time limitation of the video cassette recorders (1 hour total). However, due to somewhat faster aircraft velocities than expected and range scheduling, which caused the originally scheduled missions to be conducted in two sorties (in some instances), data were obtained for all scenes on both recorders at all altitudes.

DMAAC has agreed to digitize all five scenes on the AFFTC range although the two replaced scenes will be done on a lower priority basis and, therefore, at a later date.

2. Flight Line Tests

The preflight procedure was configured to check all recorders and systems. Antenna couplers were attached to the lower hatch to provide RF signals to the altimeters. Local control panels, altimeter indicators, and a ground digital playback unit were cabled to the pallet for ground test. An internal test signal was applied to the video processor and recorded; then the altimeter video outputs were video recorded. Both

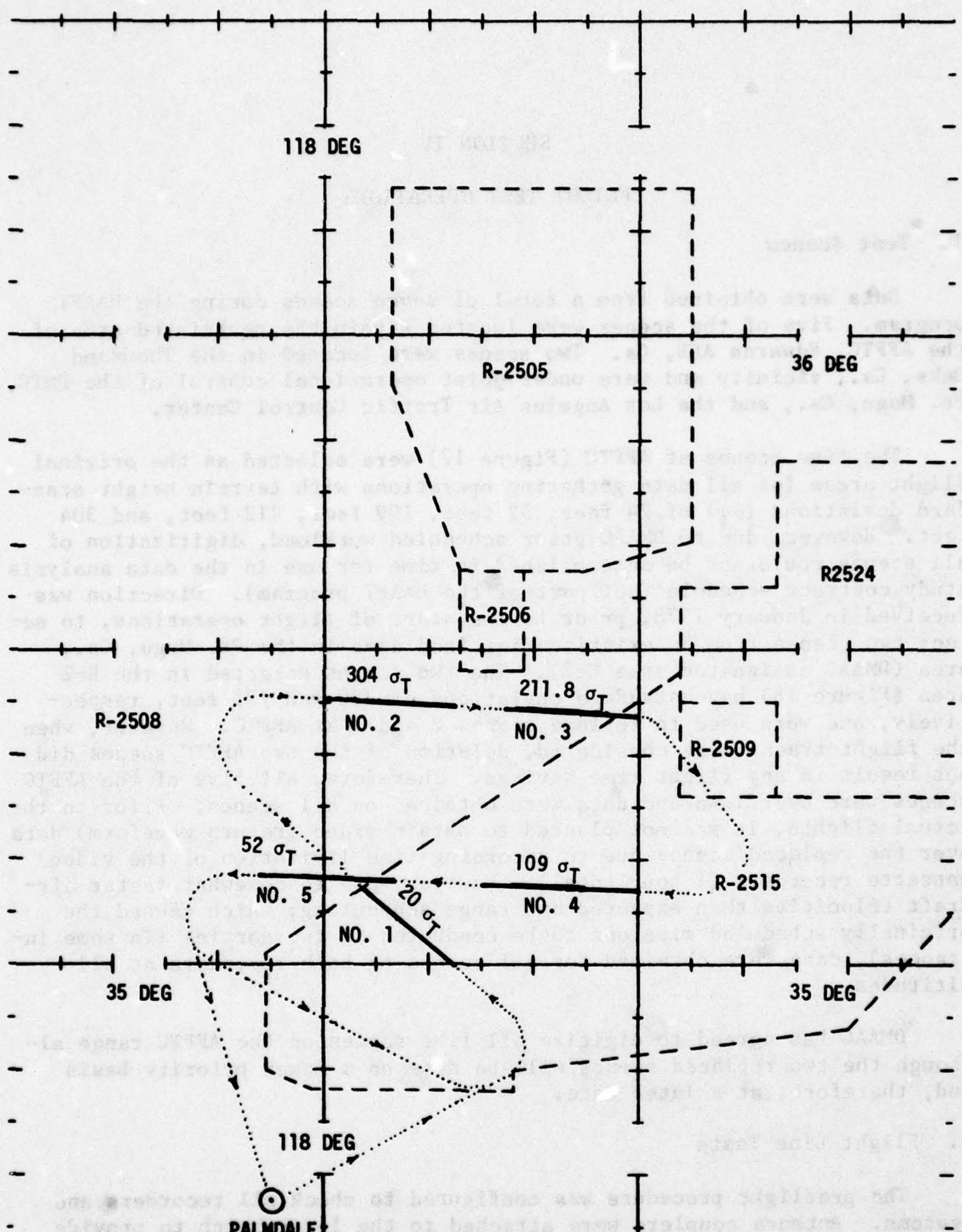


Figure 17. AFFTC Sortie Profile

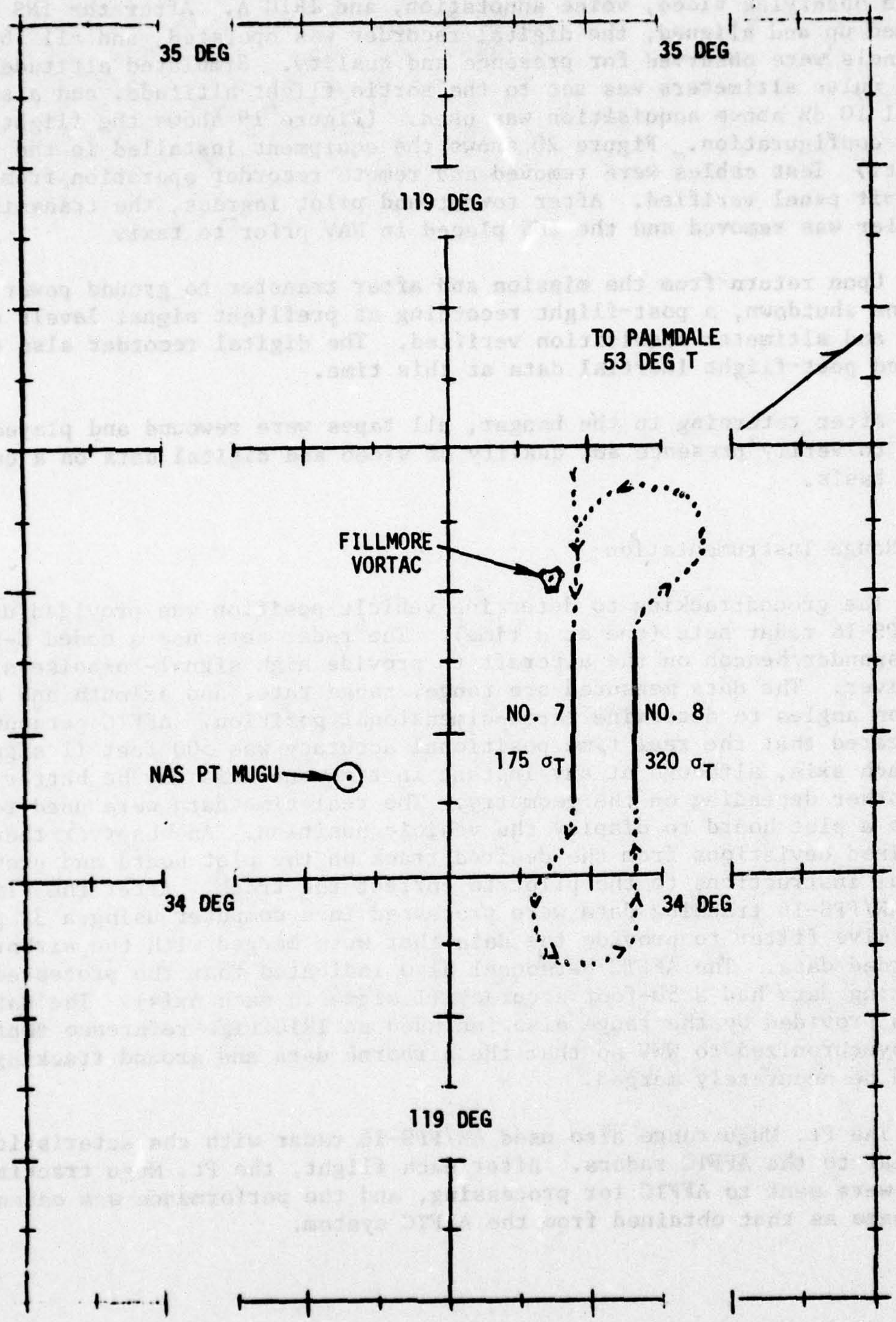


Figure 18. PMTC Sortie Profile

video recorders were then rewound and played to the end of the precal, while observing video, voice annotation, and IRIG A. After the INS had warmed up and aligned, the digital recorder was operated, and all 16 channels were observed for presence and quality. Simulated altitude for both pulse altimeters was set to the sortie flight altitude, and a signal level 10 dB above acquisition was used. (Figure 19 shows the flight line test configuration. Figure 20 shows the equipment installed in the aircraft.) Test cables were removed and remote recorder operation from the cockpit panel verified. After towout and pilot ingress, the transmitter coupler was removed and the INS placed in NAV prior to taxi.

Upon return from the mission and after transfer to ground power and engine shutdown, a post-flight recording at preflight signal levels was made and altimeter acquisition verified. The digital recorder also obtained post-flight inertial data at this time.

After returning to the hangar, all tapes were rewound and played back to verify presence and quality of video and digital data on a quick-look basis.

3. Range Instrumentation

The groundtracking to determine vehicle position was provided using AN/FPS-16 radar sets (one at a time). The radar sets use a coded C-band transponder/beacon on the aircraft to provide high signal-to-noise at the receiver. The data measured are range, range rate, and azimuth and elevation angles to determine three-dimensional position. AFFTC personnel indicated that the real time positional accuracy was 500 feet (1 sigma) in each axis, although at any instant in time one axis may be better than the other depending on the geometry. The real time data were used to drive a plot board to display the vehicle position. An observer then determined deviations from the desired track on the plot board and provided verbal instructions to the pilot to correct the track. After the flight, the AN/FPS-16 tracking data were processed in a computer using a 32 point recursive filter to provide the data that were merged with the airborne recorded data. The AFFTC personnel also indicated that the processed tracking data had a 50-foot accuracy (1 sigma in each axis). The data tapes provided by the range also included an IRIG time reference that was synchronized to WWV so that the airborne data and ground tracking data could be accurately merged.

The Pt. Mugu range also used AN/FPS-16 radar with characteristics similar to the AFFTC radars. After each flight, the Pt. Mugu tracking data were sent to AFFTC for processing, and the performance was essentially the same as that obtained from the AFFTC system.

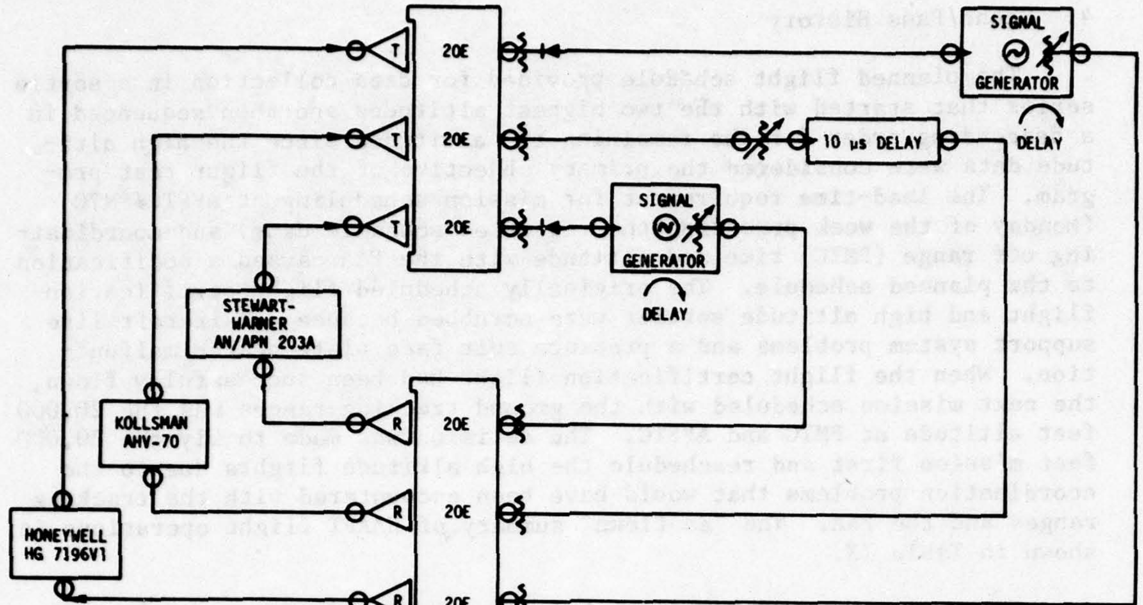


Figure 19. Altimeter Ground Test

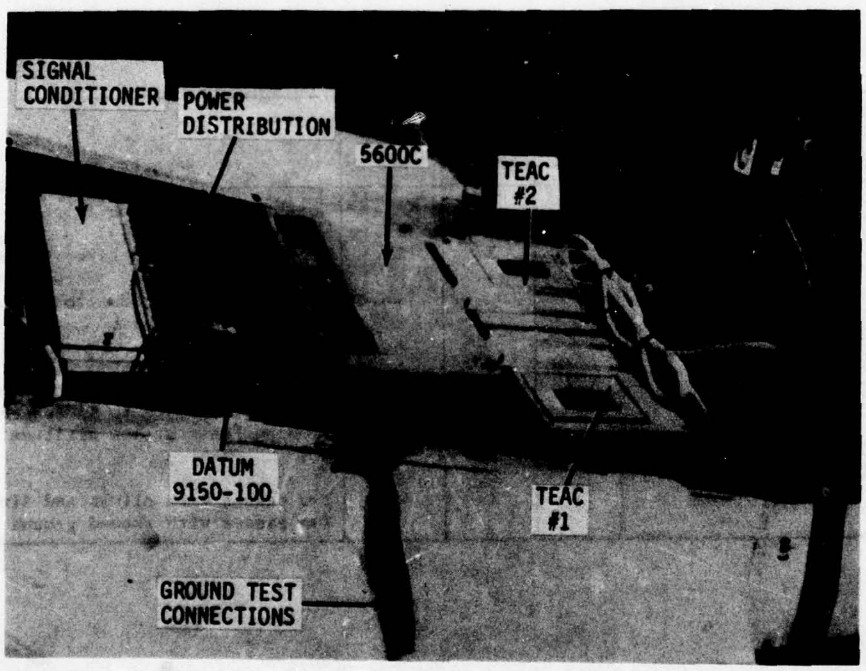


Figure 20. HAAFT Aircraft Installation

4. Scene/Pass History

The planned flight schedule provided for data collection in a sortie series that started with the two highest altitudes and then sequenced in a descending order for the remaining two altitudes since the high altitude data were considered the primary objective of the flight test program. The lead-time requirement for mission scheduling at AFFTC/PMTC (Monday of the week preceding the requested schedule date) and coordinating off range (PMTC) time and altitude with the FAA caused a modification to the planned schedule. The originally scheduled flight certification flight and high altitude sorties were scrubbed because of aircraft life support system problems and a pressure suit face plate heater malfunction. When the flight certification flight had been successfully flown, the next mission scheduled with the ground tracking ranges was the 20,000 feet altitude at PMTC and AFFTC. The decision was made to fly the 20,000 feet mission first and reschedule the high altitude flights due to the coordination problems that would have been encountered with the tracking ranges and the FAA. The "as flown" summary of HAAFT flight operations is shown in Table IX.

The missions at 30,000 feet altitude were added after the original flight series was completed due to a request for these data by another potential user of high altitude TERCOM. Data from only the AFFTC scenes were requested.

Table IX

HAAFT Flight Summary

Sortie	Date	Altitude (ft) Msl	PMTC	AFFTC	Passes/ Scene	Remarks
1	3-13-78	65,000		X	N/A	Flight certification flight
2	3-16-78	20,000	X	X	3	
3	3-24-78	45,000		X	3	High winds delayed takeoff - missed FAA window at PMTC. Scrubbed maximum altitude at AFFTC due to autopilot malfunction
4	4-3-78	45,000	X		3	
		65,000	X	X	3	
5	4-5-78	10,000	X		2	Only two passes were planned at the low altitudes due to increased flight
6	4-5-78	8,000 (5000 AGL)		X	2	time per pass at low altitude
7	5-1-78	30,000		X	3	
8	5-3-78	30,000		X	4	Two passes with climbs and dives Two passes with skewed ground tracks

SECTION V

DATA MERGING AND DUPLICATION

The primary output of the HAAFT program was the computer tapes that contained the merged flight data and ground track data. In addition, duplicates of the video cassette recordings of the return video waveforms were also provided. In producing the computer tapes, the information on the data recorder (Honeywell 5600C) was transferred into the HP 2100S computer. The ground track data were then transferred into the computer and merged with the airborne data based on the IRIG time. The total composite of data was converted to extended binary coded decimal interchange code (EBCDIC) format and recorded on 9 track, 800 BPI computer tape. Duplicates of the computer tapes were forwarded to data recipients specified in the contract (McDonnell-Douglas and The Analytic Sciences Corporation), and two copies were sent to the Air Force Avionics Laboratory. The video cassettes were not processed, but were duplicated and copies were sent to the same recipients. However, since the waveform recordings were in digital format, a D/A conversion circuit is required to view the data on an oscilloscope. A schematic of the necessary circuit and a discussion of its operation are included in Appendix A.

1. HAAFT Data Processing Flowcharts

HAAFT data processing required three major steps (Figure 21). The path of the first step required flight data tapes as source data and interpolated data files as the final output. The path of the second step required radar ground track data files as the final output. The third step took the interpolated data files and the ground track data files as source data and performed a merge operation and a convert to EBCDIC format to produce a final output tape.

In processing the HAAFT data, each individual scene is handled as a unique file for a total of 110 source data files. At the conclusion of each basic process step, the files are stored on magnetic tape for backup purposes to ensure the integrity of the data. In the process block diagram, the double arrows indicate system controlled actions and the single arrows denote manually controlled actions. The five basic process steps, which are described below, are:

1 Input flight data

2 Input radar ground track data

3 Interpolate flight data

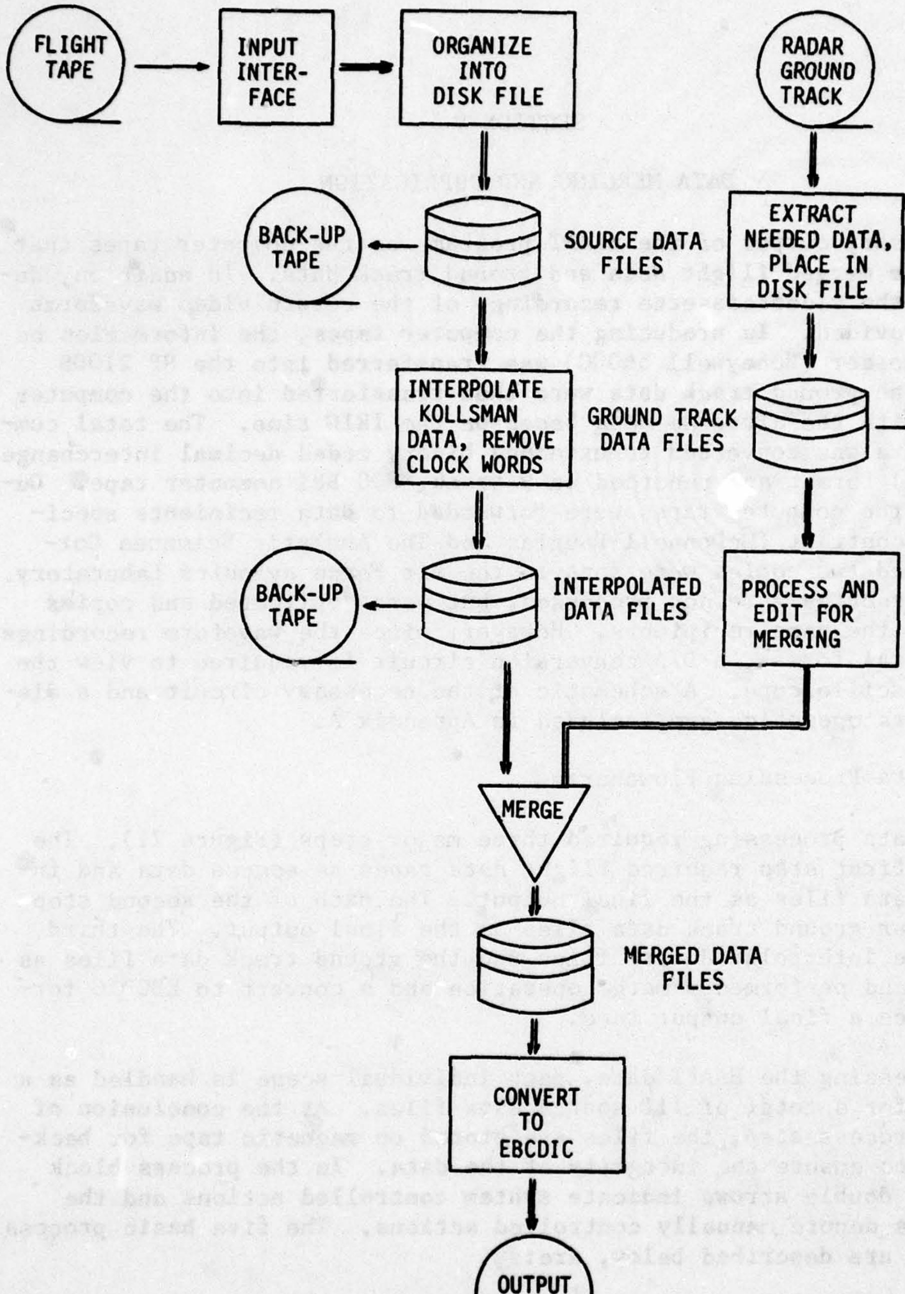


Figure 21. HAAFT Data Processing

4 Merge ground track with flight data

5 Produce output tape in EBCDIC.

The primary elements in Figure 21 are described in the following:

1 Flight Tape - The airborne data tape was recorded in real-time on 14 serial tracks. An interface was built to accumulate the serial data into buffers and output a sequence of 24 sixteen-bit words of data to the computer system every 100 milliseconds. The computer places these words into 32 word records and writes them to a disk file.

2 Radar Ground Track - The ground track data tape used is the output listing of the RADAPS data processing program. In reading this tape, the information needed for the HAAFT effort is extracted and placed in a disk file.

3 Interpolate Flight Data - Readings from the Kollsman altimeter are not available synchronized with the 100 ms timing intervals used for the data gathering. This is compensated for by linearly interpolating the values to the synchronization point of each timing period according to a clock value passed from the input interface.

4 Merge Data - The ground track data were scaled and edited and then inserted into the last eight words of the 32-word data records.

5 Output Tape - Each value in the merged file is converted to EBCDIC character representation and output to a magnetic tape.

2. Data Format

All data tapes were produced as nine track computer tapes with a density of 800 bits per inch (BPI). All data are stored as one scene, one pass per tape file, with the end of tape marked by a double end of file. Tables XII through XIX summarize the order of files on the tapes. These data are stored in EBCDIC format with six EBCDIC characters per word, 32 words per record. The order of the words, along with the definition, data range, and scaling is shown in Table X. The latitude and longitude are stored as two words, double precision; the first word is the most significant half and contains the sign. The second word is the least significant half and is unsigned. Each 16-bit word (source) is converted to EBCDIC as a 15-bit integer, plus sign. The first EBCDIC character in each output word is always zero or one for positive or negative values and negative numbers are in two's complement form. A more detailed explanation of the tape format is shown in Table XI. A detailed diagram of the double precision integer to EBCDIC conversion for the latitude and longitude words is shown in Figure 22.

TABLE X

HAAFT Output Data Structure

Word No.	Name	Data Range	Scale
1	Days	0 to 366	LSB = 1 day
2	Hours	0 to 23	LSB = 1 hour
3	Minutes	0 to 59	LSB = 1 minute
4	Seconds	0 to 59	LSB = 1 second
5	Tenths of seconds	0 to 9	LSB = 0.1 second
6	Honeywell altimeter	0 to 131070	LSB = 2 feet
7	Stewart-Warner altimeter	0 to 131070	LSB = 2 feet
8	Kollsman altimeter	0 to 98302	LSB = 1.5 feet
9	Latitude (INS) MSH	±180	MSB = ±180 degrees
10	Latitude (INS) LSH	8.38×10^{-8} to 2.75×10^{-3}	LSB = 180×2^{-31} degrees
11	Longitude (INS) MSH	±180	MSB = ±180 degrees
12	Longitude (INS) LSH	8.38×10^{-8} to 2.75×10^{-3}	LSB = 180×2^{-31} degrees
13	$\dot{X}$ INS (North velocity)	±2048	MSB = ±4096 ft/s
14	$\dot{Y}$ INS (East velocity)	±2048	MSB = ±4096 ft/s
15	$\dot{Z}$ INS (+up)	±2048	MSB = ±4096 ft/s
16	θ Pitch (+CCW)	±180	MSB = ±180 degrees
17	θ Roll (+CCW)	±180	MSB = ±180 degrees
18	Heading (+CW)	±180	MSB = ±180 degrees
19	INS altitude	0 to 262140	LSB = 4 feet
20	Baro altitude	0 to 262140	LSB = 4 feet
21	INS mode time		LSB = 1 second
22	AGC, Honeywell	0.8905 to -2.115	Full scale (8 bits) = -2.115 Vdc Zero = 0.8905 Vdc
23	AGC, Stewart-Warner	6.365 to 8.44	Full scale (8 bits) = 8.44 Vdc Zero = 6.365 Vdc
24	BFS, Kollsman	0.152 to 1.16	Full scale (8 bits) = 1.16V
25	Ground track altitude	0 to 65536	LSB = 2 feet
26	$\dot{X}_{GT}$ (East velocity)	±2048	MSB = ±2048 ft/s
27	$\dot{Y}_{GT}$ (North velocity)	±2048	MSB = ±2048 ft/s
28	$\dot{Z}_{GT}$ (+up)	±2048	MSB = ±2048 ft/s
29	Latitude (GT) MSH	±180	MSB = ±180 degrees
30	Latitude (GT) LSH		MSB = $180 \times 2^{-16} = 2.75 \times 10^{-3}$ deg
31	Longitude (GT) MSH	±180	MSB = ±180 degrees
32	Longitude (GT) LSH		MSB = $180 \times 2^{-16} = 2.75 \times 10^{-3}$ deg

MSH - Most significant half
LSH - Least significant half
MSB - Most significant bit
LSB - Least significant bit.

Table XI
HAAFT Output Tape Format

Tape is a 9-track 800 BPI.
Each file provides data from one pass over one scene.
End of the tape is marked by a double end of file (EOF).
Data are in EBCDIC; six EBCDIC characters per word, 32 words per record, 8064 characters per block.

Each record contains:

1 IRIG time, five words, unsigned: days, hours, minutes, seconds, tenths of seconds

2 Altimeter readings, three words, unsigned: Honeywell, Stewart-Warner, Kollsman

3 INS latitude, two words, signed

4 INS longitude, two words, signed

5 INS coordinate velocities, three words, signed: North, East, vertical

6 INS aircraft attitude, three words, signed: pitch, roll, true heading

7 INS altitude, one word, unsigned

8 Barometric altitude, one word, unsigned

9 INS mode time, one word, unsigned

10 AGC readings, three words, unsigned: Honeywell, Stewart-Warner, Kollsman

11 Ground track radar altitude, one word, unsigned

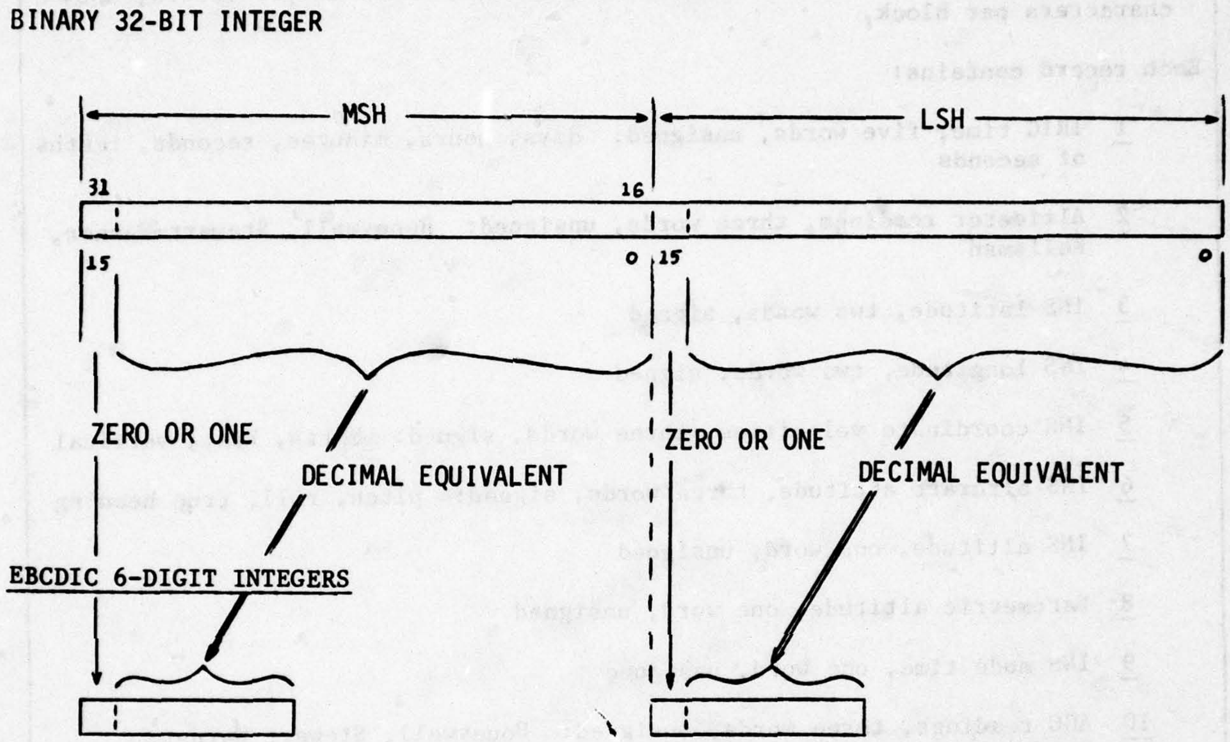
12 Radar track coordinate velocities, three words, signed: East, North, vertical

13 Radar track latitude, two words, signed

14 Radar track longitude, two words, signed

Latitude and longitude are two words (double precision); the first word is the most significant half and contains sign. The second word is unsigned.

Each 16-bit (source) word is converted to EBCDIC as a 15-bit integer, plus sign. The first EBCDIC character in each (output) word is always zero or one for positive or negative values, respectively. Negative values are in two's complement form.



BIT 31 IS SIGN BIT FOR ENTIRE 32 BITS
BIT 15 IS DATA BIT, BUT IS TREATED AS SIGN IN CONVERSION TO EBCDC

DATA RANGE: -180.00 TO 180.00 DEGREES

Figure 22. Double Precision Integer to EBCDIC Conversion

3. Data Reduction and Duplication

Reduction of the flight test recorded data and merging of the ground track data have been performed on 110 passes over seven scenes at five different altitudes. Twenty magnetic tapes have been produced and duplicated for these passes. Table XII shows the number of duplicate tapes and the altitudes included. The total time of the recorded data spans 4 hours, 17 minutes, 49 seconds at a 100 ms update rate, at 32 words per update period.

A total of 12 originals and 44 copies of the video tape cassettes, containing the video return data, was produced. Table XIII shows the number of duplicate tapes and altitudes included.

4. Deliverable Data

The order of files on the output tapes is shown in Tables XIV through XIX for the 63.5K, 45K, 20K, 10K, 30K and 30K climb and dive flights, respectively. Listed are the pass number, scene number, day number, and start and stop time reference to Greenwich mean time (ZULU). The 63.5K data span a total of 32 minutes, 34 seconds. The 45K data span 32 minutes, 30 seconds. The 30K data span 50 minutes, 9 seconds. The 10K data span 58 minutes, 31 seconds. The 30K data span 31 minutes, 55 seconds, and the 30K climb and dive data span 52 minutes, 4 seconds.

5. Data Anomalies

Due to recording difficulties, signal processing techniques, and hardware anomalies, some signals were either not recoverable or required additional processing. The anomalies associated with these signals are listed below:

1 The AGC signals (words 22, 23, and 24) were not completely recoverable due to recording difficulties on the 63.5, 45K, 20K, and 10K flights.

2 The INS and barometric altitude (words 20 and 21) overflowed due to a resolver malfunction on the 63.5K flight.

3 The Kollsman data are interpolated on the 63.5 kft, 45 kft, and 20 kft flights. This is due to the altimeter running asynchronously to the 10 sample/s recording clock, and the altimeter update time exceeding 100 milliseconds at 20 kft and above.

4 The hours (word two) on the 63.5K and 10K flights are 4 hours low due to an improper reset of the IRIG clock. However, the minutes and seconds are accurate.

5 Pass 3, scene 8 at 45 kft and pass 4, scene 5 on the 30K (climb and dive) were not recoverable due to recording difficulties.

TABLE XII

Tape Duplication

Number of Tapes	Altitude
1 original, 4 copies	63.5 kft (actual flight altitude)
1 original, 4 copies	45 kft
1 original, 4 copies	10 and 20 kft (8 kft msl at AFFTC)
1 original, 4 copies	30 and 30 kft (climb and dive)

TABLE XIII

Video Cassette Duplication

Number of Tapes	Altitude
3 originals, 12 copies	63.5, 45 kft
2 originals, 8 copies	20 kft
3 originals, 8 copies	10 kft (8 kft at AFFTC)
4 originals, 16 copies	30 kft

TABLE XIV

Order of Files - HAAFT Output Tape - 10K

Pass	Scene	Day No.	Start Time	Stop Time
1	1 Edwards	093	23:02:25.4	23:06:24.0
1	2 Edwards	093	23:16:49.5	23:20:17.0
1	3 Edwards	093	23:21:49.1	23:25:15.0
1	4 Edwards	093	23:34:22.6	23:39:00.0
1	5 Edwards	093	23:41:35.4	23:45:36.0
1	7 Pt. Mugu	093	19:06:17.6	19:10:43.5
1	8 Pt. Mugu	093	19:13:47.7	19:17:31.5
2	1 Edwards	093	23:57:36.6	00:01:12.0
2	2 Edwards	094	00:09:34.4	00:13:15.0
2	3 Edwards	094	00:14:53.9	00:18:26.0
2	4 Edwards	094	00:26:38.0	00:31:29.0
2	5 Edwards	094	00:34:10.3	00:38:03.0
2	7 Pt. Mugu	093	19:22:40.4	19:26:50.5
2	8 Pt. Mugu	093	19:30:37.4	19:34:45.0

TABLE XV

Order of Files - HAAFT Output Tape - 20K

Pass	Scene	Day No.	Start Time	Stop Time
1	1 Edwards	076	15:43:31.6	15:45:55.0
1	2 Edwards	076	15:54:36.4	15:56:45.9
1	3 Edwards	076	15:57:44.6	15:59:50.9
1	4 Edwards	076	16:09:06.4	16:11:54.0
1	5 Edwards	076	16:13:30.8	16:15:53.9
1	7 Pt. Mugu	076	14:48:41.2	14:51:15.1
1	8 Pt. Mugu	076	14:55:38.6	14:58:15.0
2	1 Edwards	076	16:30:16.7	16:32:37.8
2	2 Edwards	076	16:39:44.2	16:41:54.0
2	3 Edwards	076	16:42:58.1	16:45:00.0
2	4 Edwards	076	16:53:24.2	16:56:13.0
2	5 Edwards	076	16:57:45.6	17:00:10.0
2	7 Pt. Mugu	076	15:02:21.7	15:04:51.5
2	8 Pt. Mugu	076	15:08:21.9	15:11:02.2
3	1 Edwards	076	17:13:56.6	17:16:15.0
3	2 Edwards	076	17:23:29.9	17:25:39.0
3	3 Edwards	076	17:26:40.3	17:28:44.0
3	4 Edwards	076	17:36:22.7	17:39:06.0
3	5 Edwards	076	17:40:39.9	17:43:06.0
3	7 Pt. Mugu	076	15:15:28.3	15:17:55.0
3	8 Pt. Mugu	076	15:21:17.3	15:23:23.0

TABLE XVI

Order of Files - HAAFT Output Tape - 45K

Pass	Scene	Day No.	Start Time	Stop Time
1	1 Edwards	083	20:04:53.3	20:06:44.0
1	2 Edwards	083	20:12:39.0	20:13:58.5
1	3 Edwards	083	20:14:36.0	20:15:54.0
1	4 Edwards	083	20:20:56.3	20:23:01.0
1	5 Edwards	083	20:24:12.1	20:26:01.0
1	7 Pt. Mugu	083	17:16:39.0	17:18:19.5
1	8 Pt. Mugu	083	18:00:01.1	18:01:28.5
2	1 Edwards	083	20:36:07.1	20:37:51.4
2	2 Edwards	083	20:43:35.1	20:44:57.0
2	3 Edwards	083	20:45:34.2	20:46:53.0
2	4 Edwards	083	20:53:37.2	20:55:44.0
2	5 Edwards	083	20:56:53.7	20:58:39.0
2	7 Pt. Mugu	083	17:27:38.6	17:29:08.5
2	8 Pt. Mugu	083	17:33:47.2	17:34:58.5
3	1 Edwards	083	21:11:33.5	21:13:18.0
3	2 Edwards	083	21:19:17.6	21:20:41.0
3	3 Edwards	083	21:21:19.1	21:22:40.0
3	4 Edwards	083	21:28:09.1	21:30:12.0
3	5 Edwards	083	21:31:22.8	21:33:09.0
3	7 Pt. Mugu	083	17:39:35.1	17:41:16.5

Note: No scene 8 for pass 3.

TABLE XVII

Order of Files - HAAFT Output Tape - 63.5K

Pass	Scene	Day No.	Start Time	Stop Time
1	1 Edwards	092	19:48:31.4	19:50:01.0
1	2 Edwards	092	19:56:07.6	19:57:33.0
1	3 Edwards	092	19:58:13.6	19:59:37.0
1	4 Edwards	092	00:04:51.9	00:06:43.0
1	5 Edwards	092	00:07:47.6	00:09:24.0
1	7 Pt. Mugu	092	18:27:34.5	18:29:08.0
1	8 Pt. Mugu	092	18:34:50.3	18:36:20.0
2	1 Edwards	092	00:21:56.1	00:23:26.0
2	2 Edwards	092	00:29:26.0	00:30:55.0
2	3 Edwards	092	00:31:36.2	00:33:01.0
2	4 Edwards	092	00:39:25.3	00:41:16.0
2	5 Edwards	092	00:42:20.4	00:43:56.0
2	7 Pt. Mugu	092	18:41:57.0	18:43:38.0
2	8 Pt. Mugu	092	28:48:50.1	18:50:16.0
3	1 Edwards	092	00:55:35.1	00:57:04.0
3	2 Edwards	092	01:03:00.1	01:04:24.0
3	3 Edwards	092	01:05:04.0	01:06:24.3
3	4 Edwards	092	01:12:05.7	01:13:57.0
3	5 Edwards	092	01:15:02.8	01:16:39.0
3	7 Pt. Mugu	092	18:55:26.3	81:57:06.0
3	8 Pt. Mugu	092	19:01 56.4	19:03:24.0

TABLE XVIII

Order of Files - HAAFT Output Tape - 30K

Pass	Scene	Day No.	Start Time	Stop Time
1	1	121	16:03:23.0	16:05:50.0
1	2	121	16:12:43.0	16:14:50.0
1	3	121	16:18:08.6	16:18:07.0
1	4	121	16:24:51.0	16:27:05.9
1	5	121	16:28:23.0	16:30:19.0
2	1	121	16:43:37.0	16:45:43.0
2	2	121	16:53:11.0	16:55:20.0
2	3	121	16:56:23.0	16:58:35.0
2	4	121	17:05:10.0	17:07:24.0
2	5	121	17:08:41.0	17:10:39.0
3	1	121	17:22:53.0	17:24:55.0
3	2	121	17:31:43.0	17:33:54.0
3	3	121	17:34:54.0	17:37:10.0
3	4	121	17:44:01.0	17:46:13.0
3	5	121	17:47:31.0	17:49:29.0

TABLE XIX

Order of Files - HAAFT Output Tape - 30K Climb and Dive

Pass	Scene	Day No.	Start Time	Stop Time
1	1	123	16:15:03.0	16:18:15.0
1	2	123	16:28:20.0	16:30:22.0
1	3	123	16:31:16.0	16:33:18.0
1	4	123	16:42:23.0	16:45:35.0
1	5	123	16:47:27.0	16:50:27.0
2	1	123	17:02:23.0	17:05:31.0
2	2	123	17:13:37.0	17:15:41.0
2	3	123	17:16:34.0	17:18:35.0
2	4	123	17:26:11.0	17:29:30.0
2	5	123	17:31:11.0	17:34:11.0
3	1	123	17:47:05.0	17:50:16.0
3	2	123	17:57:35.0	17:59:53.0
3	3	123	18:00:57.0	18:03:12.0
3	4	123	18:10:12.0	18:13:29.0
3	5	123	18:15:35.0	18:18:38.0
4	1	123	18:32:05.0	18:35:10.0
4	2	123	18:42:49.0	18:45:10.0
4	3	123	18:46:13.0	18:48:27.0
4	4	123	18:54:58.0	18:58:18.0
Note: No scene 5 pass 4.				

6. Data Analysis

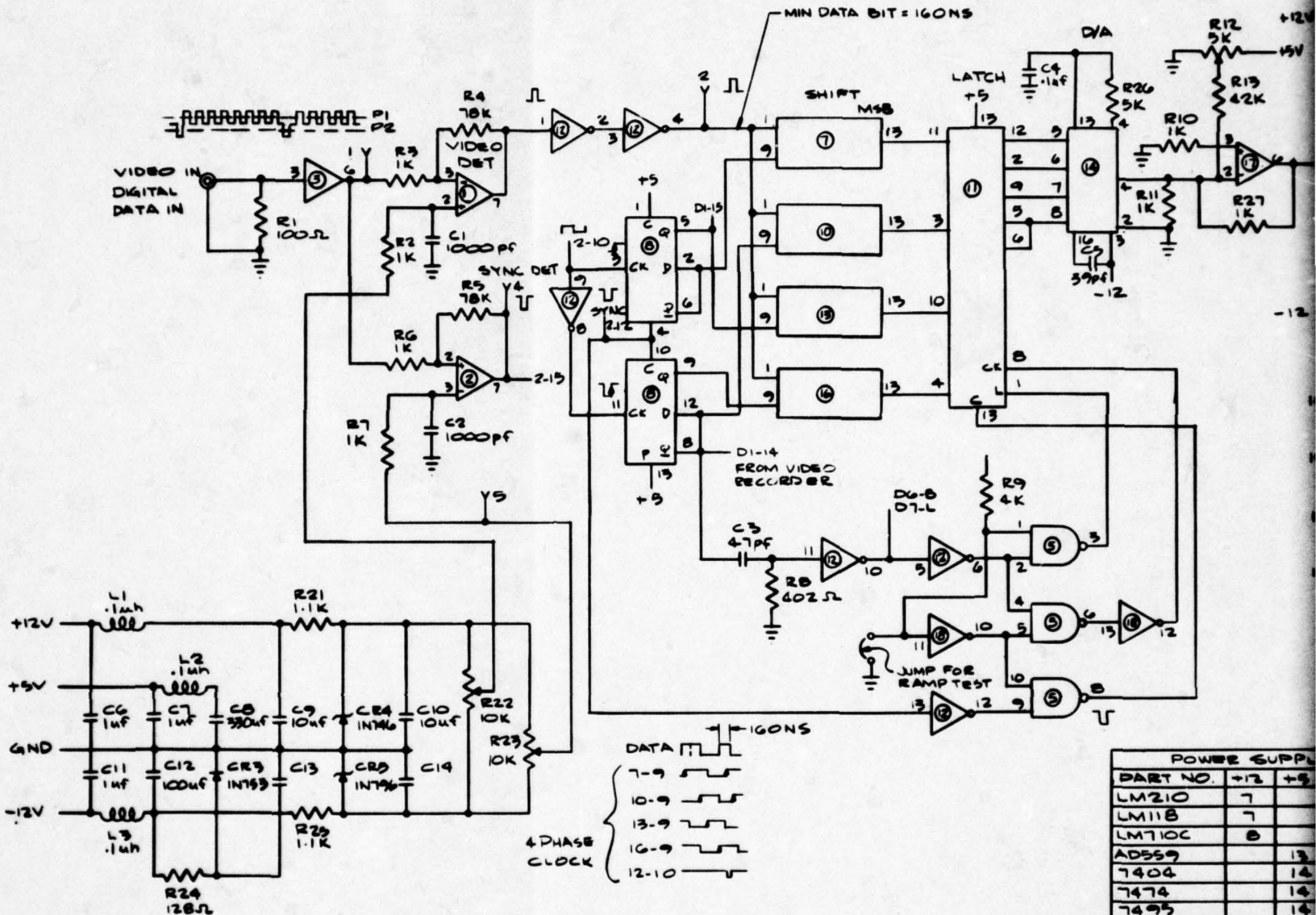
Preliminary data analysis was conducted on the first pass of each of the seven scenes for four altitudes, 63.5K, 45K, 20K, and 10K, respectively. This analysis was used to evaluate the quality of the data prior to conclusion of the flight test program to assure that useful data had been gathered. Although there were occasional problems with the sensors, the problems were not sufficiently serious to justify repeating any of the flights. Sample plots are shown in Appendix B. These include raw data plots, detrended data, auto correlations, and power spectral densities for the three altimeters at 63.5K, 45K, 20K, and 10K altitudes, recorded over scenes 4 and 7.

APPENDIX A

Video Decoder

The serial digital video data are recorded at 3.25 MHz without its associated clock, and, therefore, a decoder is required to strip the recorded data from the tape, reformat the data into four-bit words, and provide an analog output display. This is achieved by measuring the intra-synch pulse time interval and developing a signal error count, which is then used to adjust the frequency of a free-running oscillator. This operation is accomplished each 400 microseconds to maintain close control of the operating clock frequency, which must match the recording clock of 3.25 MHz. Figures A-1 and A-2 present the schematic diagrams of the two cards necessary to implement the video decoder circuits.

The digital data from the tape drive two comparator circuits, one to strip off the negative synch pulse, and the other to quantize the data into a one-zero data stream. The serial data are decommutated into four-bit data words, which are D/A converted in an AD-559 that drives the output amplifier V17. The synch pulse is used by the clock generator circuit from which the 3.25 MHz clock is derived. The free-running 12 MHz oscillator V3 is offset in frequency via the varacter diode TRW 27824, and is transformer coupled to the clock circuitry via TT211 and buffer V9. The synch pulse is used to clear a synchronous counter, which is then counted up to its terminal state. The digital error count is produced in the four-bit counter, V10, which is preset to state 7. This represents the maximum negative error while state 15 represents the maximum positive error that provides a dynamic range of plus and minus one word. The latch V13 is loaded at the end of each measurement cycle and D/A converted in V16 and buffered in V19. This analog error voltage drives the varacter tuning diode in the oscillator.



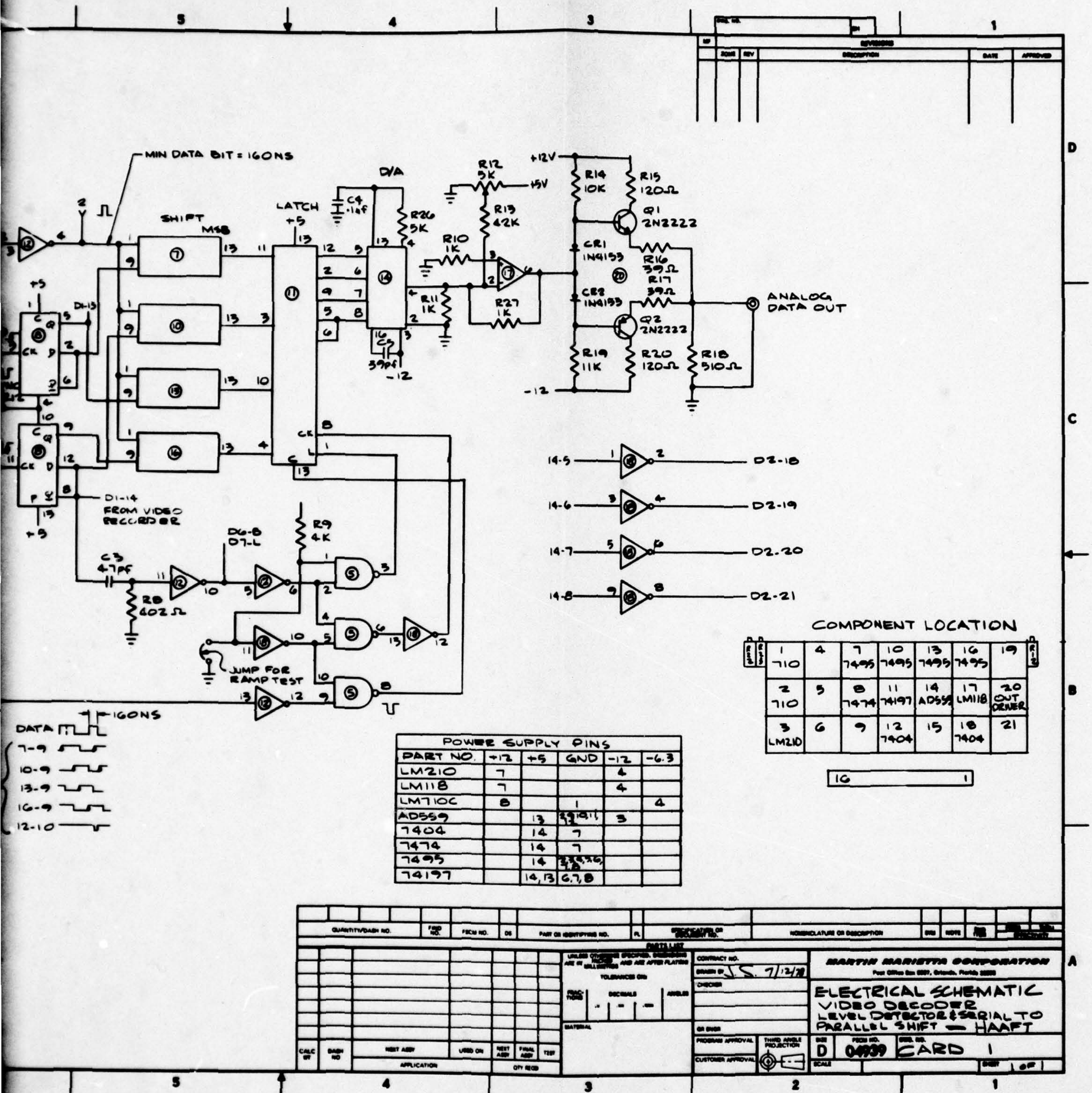
POWER SUPP[LY]		
PART NO.	+12	+5
LM210	7	
LM118	7	
LM710C	8	
AD559		13
7404		14
7474		14
7495		14
74197		14,

NOTES:

1. LAST REF DES: R27, C14, CR5 & Q2
2. ALL RESISTORS ARE 1/4 W

QUANTITY/DASH NO. NEXT ASSY USED ON APPLICATION

1



POWER SUPPLY PINS					
PART NO.	+12	+5	GND	-12	-6.3
LM210	7			4	
LM118	7			4	
LM710C	8		1		4
AD559		13	2,9,10,11,12	3	
7404		14	7		
7474		14	7		
7495		14	2,3,4,5,6,7,8		
74197		14,13	6,7,8		

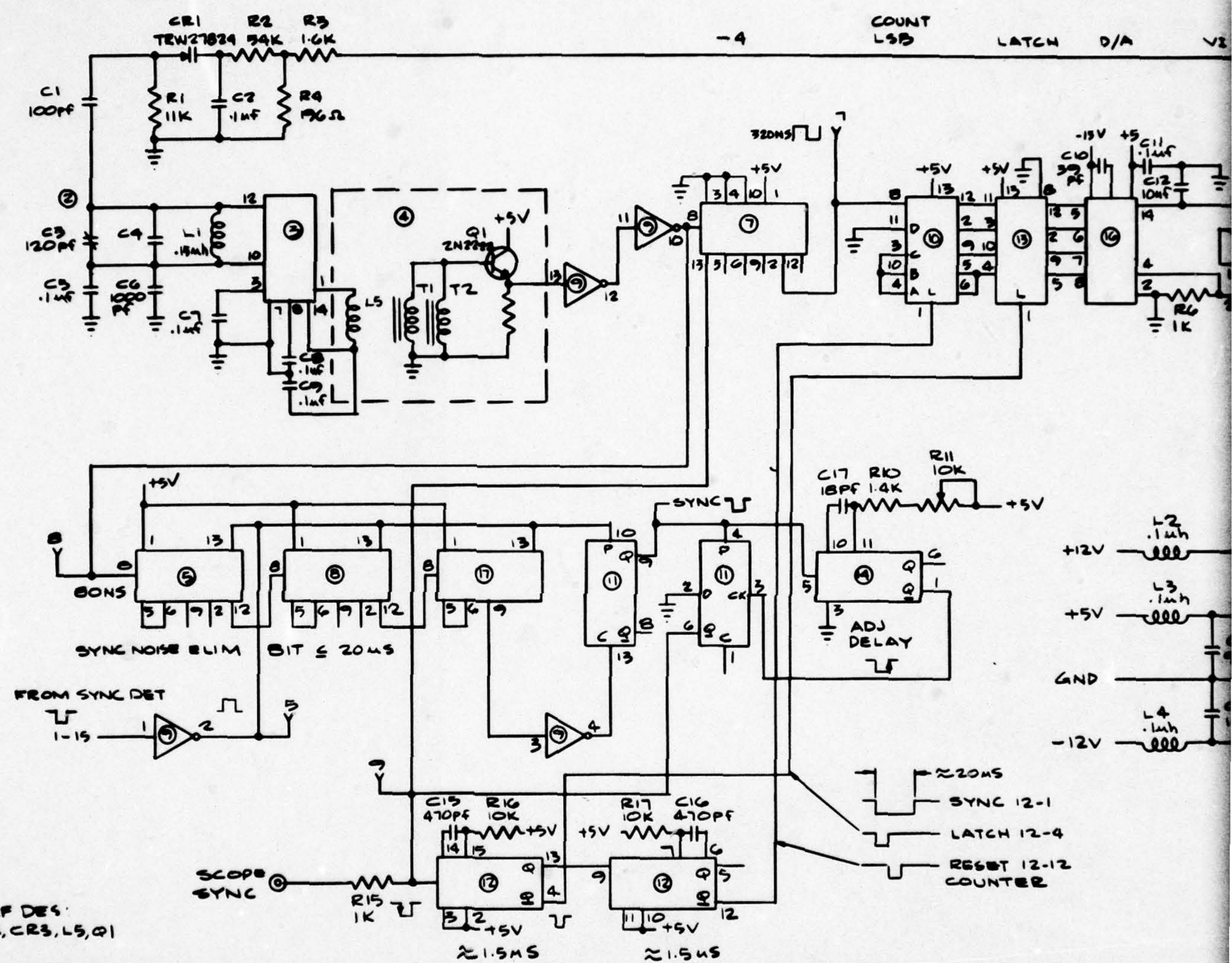
COMPONENT LOCATION

1 710	4	7 7495	10 7495	13 7495	16 7495	19
2 710	5	8 7474	11 74197	14 AD559	17 LM118	20 OUT DRIVER
3 LM210	6	9	12 7404	15	18 7404	21

Figure A-1. Electrical Schematic Video Decoder Level Detector and Serial to Parallel Shift

Card 1 - Part Lists

Index	Quantity	Part No.	Manufacturing	Description
1,2	2	LM 710C	National	IC voltage comparator
3	1	LM 210	National	IC voltage follower
7,10 13,16	4	SN 7495N	TI	IC shift register
8	1	SN 7474N	TI	IC dual D flipflop
12,18	2	SN 7404N	TI	IC hex inverter
11	1	SN 74197N	TI	IC binary counter/latch
14	1	AD559	Analog Devices	IC 8 bit D/A converter
17	1	LM118	National	IC op amp
20	1	JAN2N2222A	QPL-19500	NPN transistor
20	1	JAN2N2907A	QPL-19500	PNP transistor
20	2	JAN1N4153	QPL-19500	Diode
R_7, R_6 R_2, R_3 R_{27}, R_{11} R_{10}	7	CC1001F	Allen Bradley	1 KΩ resistor 1/4W
R_{21}, R_{25}	2	CC1101F	Allen Bradley	1.1 KΩ resistor 1/4W
R_5, R_4	2	CC7872F	Allen Bradley	78.7 KΩ resistor 1/4W
R_{20}, R_{15}	2	CC1210F	Allen Bradley	121 KΩ resistor 1/4W
R_{16}, R_{17}	2	CC38R3F	Allen Bradley	38.3Ω resistor 1/4W
R_{24}	1	CC1270F	Allen Bradley	127Ω resistor 1/4W
R_1	1	CC1000F	Allen Bradley	100Ω resistor 1/4W
R_{25}	1	CC5111F	Allen Bradley	5.11 KΩ resistor 1/4W
R_{13}	1	CC4222F	Allen Bradley	42.2 KΩ resistor 1/4W
R_{14}	1	CC1002F	Allen Bradley	10 KΩ resistor 1/4W
R_{19}	1	CC1102F	Allen Bradley	11 KΩ resistor 1/4W
R_9	1	CC4021F	Allen Bradley	4.02 KΩ resistor 1/4W
R_8	1	CC4020F	Allen Bradley	402 Ω resistor 1/4W
R_{22}, R_{23}	2	RJ24FX103	QPL-22097	10 KΩ potentiometer
R_{12}	1	RJ24FX502	QPL-22097	5 KΩ potentiometer
C_6, C_7 C_{11}	3	M39014/02-0403, /-1403	QPL-39014	1 μF capacitor
C_{13}, C_{14} C_{10}	3	M39003/01-2286	QPL-39003	10 μF capacitor
C_9, C_{12}	2	M39003/01-2301	QPL-39003	100 μF capacitor
C_1, C_2	2	M39014/01-0397, /-1397	QPL-39014	1000 pF capacitor
C_7	1	M39003/01-2251	QPL-39003	330 μF capacitor
C_3	1	CMR05E470GODL	QPL-39001	47 pF capacitor
C_4	1	M39014/01-0391 /-1391	QPL-39014	0.1 μF capacitor
L_1, L_2 L_3	3	MS18130-1	QPL-15305	0.15 μH inductor
CR_4, CR_5	2	JAN1N746A	QPL-19500	Zener diode 3.3V
CR_3	1	JAN1N753	QPL-19500	Zener diode 6.2V
	1	3662	Vector	Plugboard 44 pins
	10	102-14-CC-C	Garry	Sockets 14 pin dual in-line
	2	8-ICS	Cinch	8 lead to 5 socket
	1	102-16-CC-C	Garry	Socket 16 pin dual in-line
	2	M39024/11-03	QPL-39024	Test, jack tips black
	8	M39024/11-01	QPL-39024	Test, jack tips white
	2	M39012/21-0003	QPL-39012	BNC receptacle, D hole



NOTES:

1. LAST REF DES: R22, C22, CR3, L5, Q1 & T2
2. ALL RESISTORS ARE 1/4 W.

COMPONENT LOCATION

1	4	7 197	10 197	13 127	16 AD559	19 747
2	5 197	8 197	11 7474	14 121	17 197	20
3 LVA 47A	6 MC648	9 04	12 123	15	18	21

16 1

QUANTITY/DASH NO.	FIND NO.	FSCM NO.	DS	PART NO.

CALC BY	DASH NO	NEXT ASSY	USED ON	NEXT ASSY	FINAL ASSY	TEST
		APPLICATION		QTY REQD		

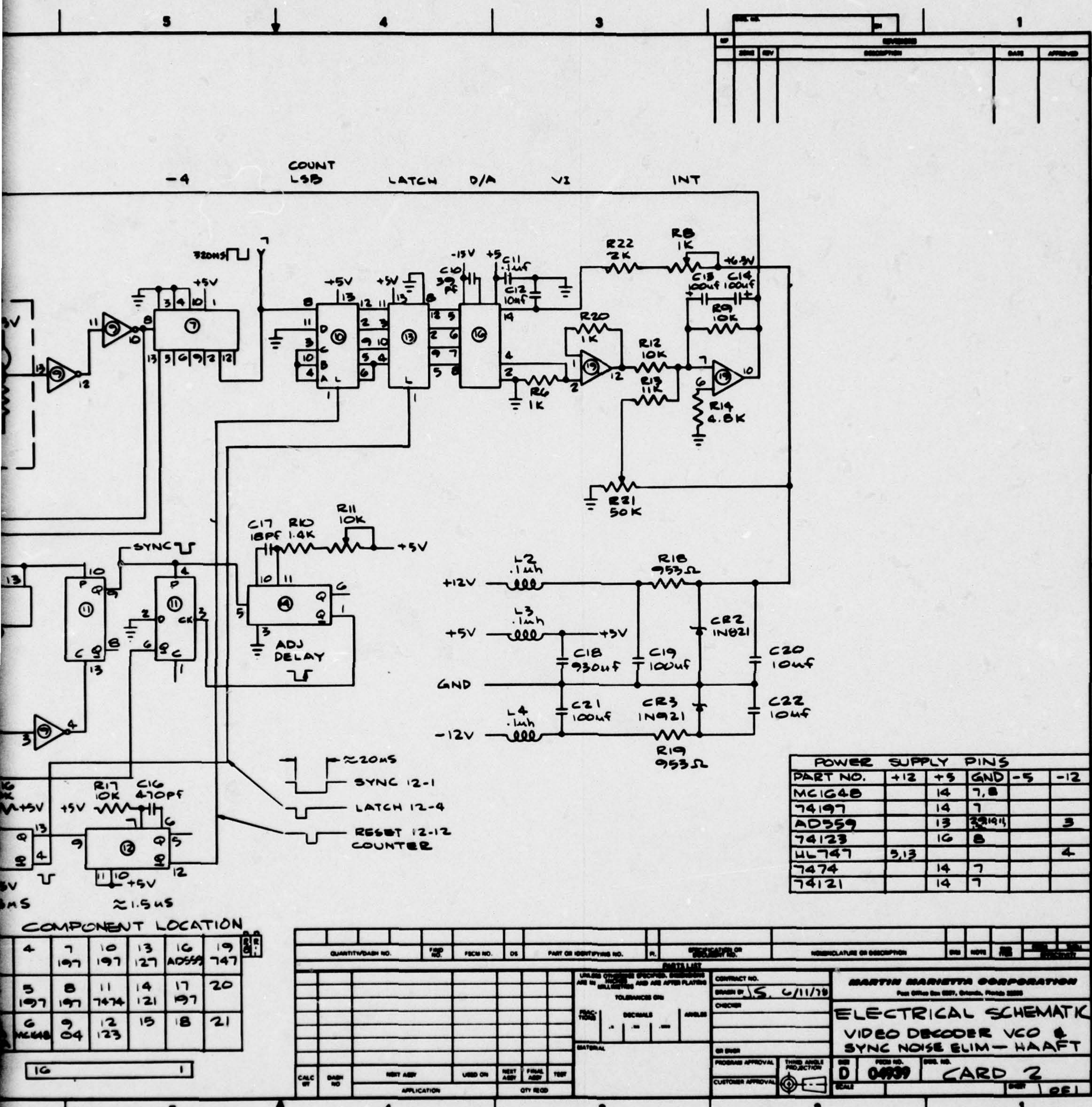


Figure A-2. Electrical Schematic Video Decoder VCO and Sync Noise Elimination

Card 2 - Part Lists

Index	Quantity	Part No.	Manufacturer	Description
3	1	MC1648	Motorola	IC
5,7 8,10 13,14	6	SN 74197N	TI	IC
11	1	SN 7474N	TI	IC
12	1	SN 74123N	TI	IC
14		SN 74121N	TI	IC
16	1	AD559	Analog Devices	D/A converter
19	1	U7A7747312	Fairchild	IC MA 747 op amp
4	1	JAN2N2222		NPN transistor
CR_2, CR_3	2	1N821		Zener diode 6.2V
CR_1	1	27824	TRW	Varactor diode
R_{16}, R_{17} R_{12}, R_{19}	4	CC1002F	Allen Bradley	10 KΩ resistor 1/4W
R_6, R_{20} R_{15}	3	CC1001F	Allen Bradley	1 KΩ resistor 1/4W
R_1, R_{13}	2	CC1102F	Allen Bradley	11 KΩ resistor 1/4W
R_{18}, R_{19}	2	CC9530F	Allen Bradley	953Ω resistor 1/4W
R_2	1	CC5362F	Allen Bradley	53 KΩ resistor 1/4W
R_4	1	CC1960F	Allen Bradley	196Ω resistor 1/4W
R_{22}	1	CC3651F	Allen Bradley	2 KΩ resistor 1/4W
R_3	1	CC1621F	Allen Bradley	1.6 KΩ resistor 1/4W
R_9	1	CC4871F	Allen Bradley	4.8 KΩ resistor 1/4W
R_1	1	CC2051F	Allen Bradley	2 KΩ resistor 1/4W
R_{18}	1	RJ24FX102	QPL-22097	1 KΩ potentiometer 1/2W
C_{21}, C_{19} C_{13}, C_{14}	4	M39003101-2301	QPL-39003	100 μF capacitor 20V
	7	M39014102-0391	Vitramon	0.1 μF capacitor 100V
C_{20}, C_{22} C_{12}	3	M39003/01 -2286	QPL-39003	10 μF capacitor 20V
C_{16}, C_{15}	2	M39014/01-0391/ -1391	Vitramon	470 pF capacitor
C_{18}	1	M39014/01-0388/ -1388	Vitramon	330 μF capacitor
	1	M39014/01-0397 -1397	Vitramon	1000 pF capacitor
C_4	1	CMR05F121GODL	QPL-39001	120 pF capacitor 500V
C_1	1	CMR05F101GODL	QPL-39001	100 pF capacitor 500V
C_{10}	1	CMR05E390GODL	QPL-39001	39 pF capacitor 500V
C_3	1	538-037D9-35PF	EIRE	Variable capacitor 9-35P
L_2, L_3 L_4	3	MS18130-1	QPL-15305	0.5 μH inductor
L_1	1	MS18130-1	QPL-15305	0.15 μH inductor
R_{21}	1	93H9-8	CC1-93H9	10 turn variable pot
R_{18}	1	RJ24FX103	QPL-22097	10K pot 1/2W
	1	3662	Vector	Plugboard 44 pins
	1	RG44	Vector	Connector
	5	102-14-CC-C	Garry	Sockets 14 pin dual in-line
	2	102-16-CC-C	Garry	Sockets 16 pin dual in-line
	1	M39024/11-03	QPL-39024	Test, jack tips black
	9	M39024/11-01	QPL-39024	Test, jack tips white

APPENDIX B

FLIGHT DATA ANALYSIS

The quick-look analysis was required by contract to determine whether the flight hardware was operating properly. This quick-look analysis consisted of two efforts. Immediately after the flight, the data on the recorders were examined on an oscilloscope to determine whether there was recorded data on each channel. Since the information on the data recorded was in digital format, the presence of digital bits was verified. The actual data could not be evaluated to any significant degree on the flight line. However, the return waveform data could be viewed since the flight test crew had a video decoder circuit. The flight data were then sent to Martin Marietta for a more detailed evaluation. These were then transferred into the HP-5451B computer to be displayed and processed. The figures presented in this appendix are sample plots of the data that were gathered and processed. The plots involve the unprocessed (raw) altitude data, the same data with the mean and trend removed and rescaled for visibility, the autocorrelation functions, and the power spectral densities. Data from scene 4 (σ_T = 109 feet on the AFFTC range) and, scene 7 (σ_T = 174 feet in the Pt. Mugu, California, area) are presented for all altitudes except the last flight series (30K), as indicated in Table B-I.

This analysis was conducted to determine whether a mission should be repeated. It will be noted that at the higher altitudes there were occasional data interruptions. This was not due to an altimeter malfunction, but a marginal sensitivity, which was a characteristic of that altimeter. Further, all altimeters were tested immediately after return of the aircraft and no malfunctions were detected. Therefore, no missions were repeated. In order to expand the data base and thus perform signal analysis on more passes, a reasonability test was implemented during data reduction, and interpolation is performed on the altimeter data when a data interruption occurs. The detailed analysis and evaluation of the flight data will be conducted under another program.

TABLE B-I

Data Plots

Figure No.	Pass	Scene	Altitude (MSL)x10^{-3}	Altimeter	Type Plot
B-1	1	4	63.5	HI	Raw-(Feet)
B-2				SW	
B-3				K	
B-4			45	HI	
B-5				SW	
B-6				K	
B-7			20	HI	
B-8				SW	
B-9				K	
B-10			8	HI	
B-11				SW	
B-12				K	Raw-(Feet)
B-13			63.5	HI	Detrended-(Feet)
B-14				SW	
B-15				K	
B-16			45	HI	
B-17				SW	
B-18				K	
B-19			20	HI	
B-20				SW	
B-21				K	
B-22			8	HI	
B-23				SW	
B-24				K	Detrended-(Feet)
B-25			63.5	HI	Auto Correlation (ft^2)
B-26				SW	
B-27				K	
B-28			45	HI	
B-29				SW	
B-30				K	
B-31			20	HI	
B-32				SW	
B-33				K	
B-34			8	HI	
B-35				SW	Auto Correlation (ft^2)
B-36				K	
B-37			63.5	HI	PSD-(ft^2/Hz)
B-38				SW	
B-39				K	
B-40			45	HI	
B-41				SW	
B-42				K	
B-43			20	HI	
B-44				SW	
B-45	1	4		K	PSD-(ft^2/Hz)

TABLE B-I (Continued)

Figure No.	Pass	Scene	Altitude (MSL)x10^{-3}	Altimeter	Type Plot
B-46	1	4	8	HI	PSD-(ft^2/Hz)
B-47		4		SW	
B-48		4		K	PSD (ft^2/Hz)
B-49		7	63.5	HI	Raw-(Feet)
B-50				SW	
B-51				K	
B-52			45	HI	
B-53				SW	
B-54				K	
B-55			20	HI	
B-56				SW	
B-57				K	
B-58			10	HI	
B-59				SW	
B-60				K	Raw-(Feet)
B-61			63.5	HI	Detrended-(Feet)
B-62				SW	
B-63				K	
B-64			45	HI	
B-65				SW	
B-66				K	
B-67			20	HI	
B-68				SW	
B-69				K	
B-70			10	HI	
B-71				SW	
B-72				K	Detrended-(Feet)
B-73			63.5	HI	Auto Correlation (ft^2)
B-74				SW	
B-75				K	
B-76			45	HI	
B-77				SW	
B-78				K	
B-79			20	HI	
B-80				SW	
B-81				K	
B-82			10	HI	
B-83				SW	Auto Correlation (ft^2)
B-84				K	
B-85			63.5	HI	PSD-(ft^2/Hz)
B-86				SW	
B-87				K	
B-88			45	HI	
B-89				SW	
B-90				K	
B-91			20	HI	
B-92				SW	
B-93				K	
B-94			10	HI	
B-95				SW	
B-96	1	7		K	PSD (ft^2/Hz)

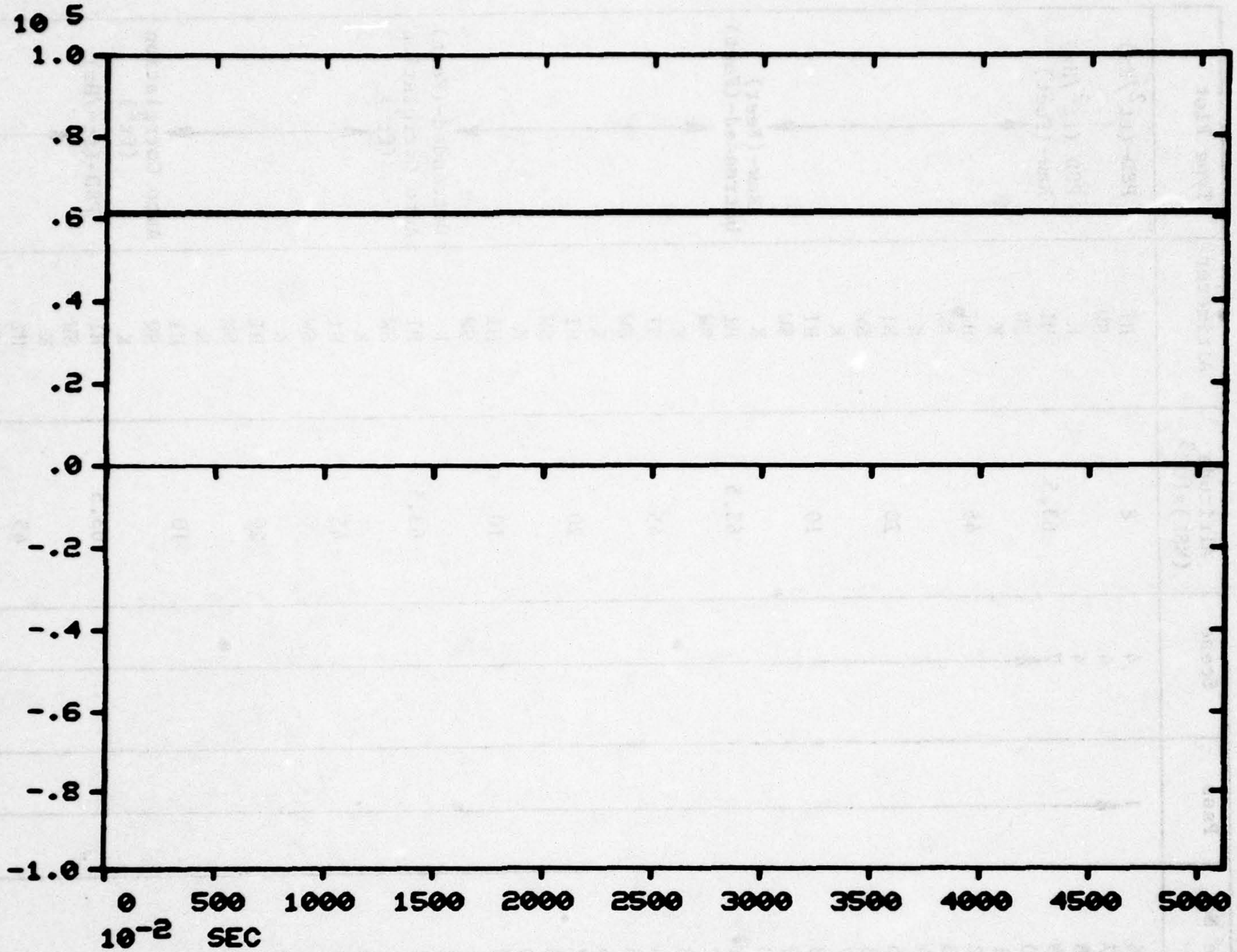


Figure B-1. Honeywell 63.5K Raw Data, Scene 4

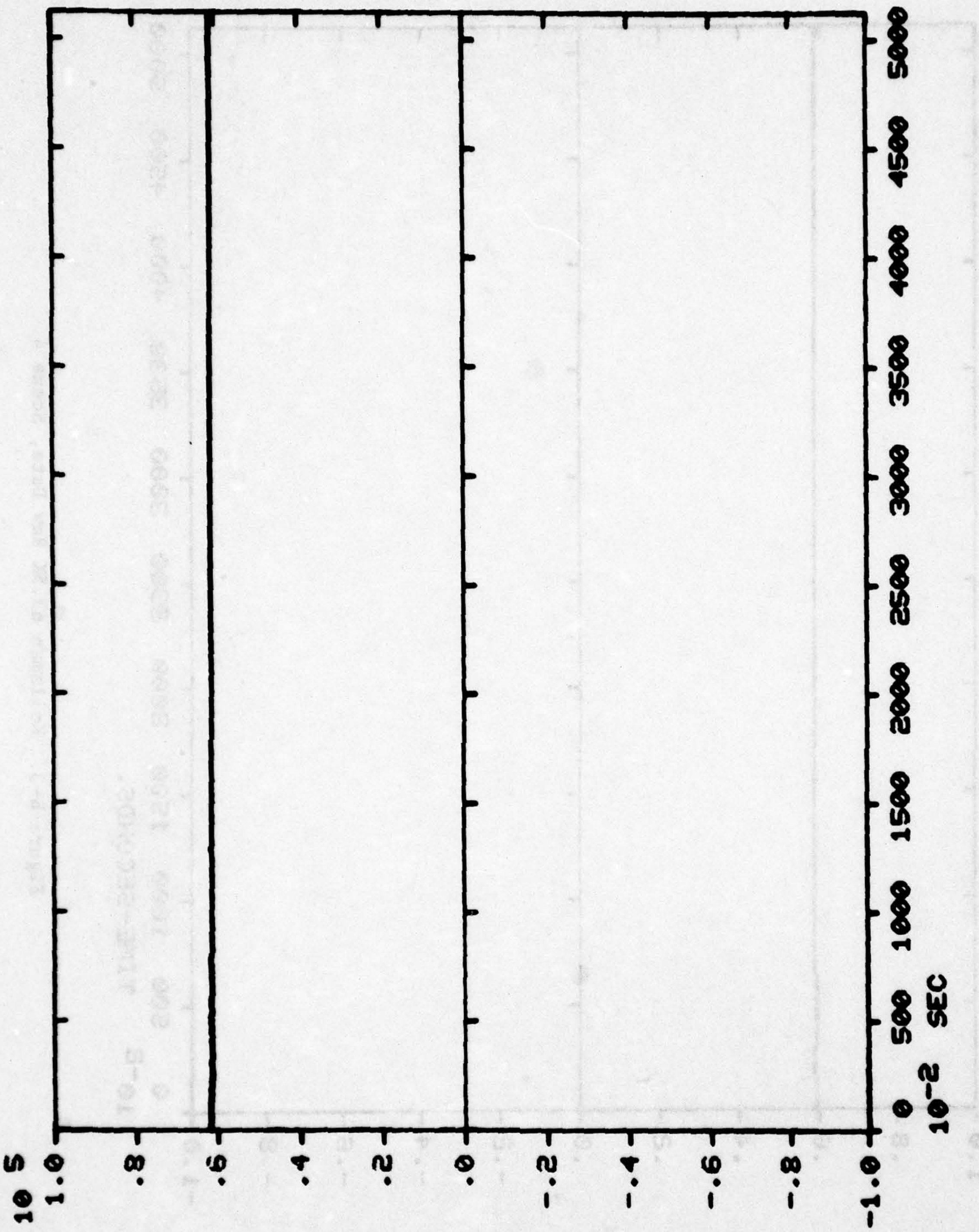


Figure B-2. Stewart-Warner 63.5K Raw Data, Scene 4

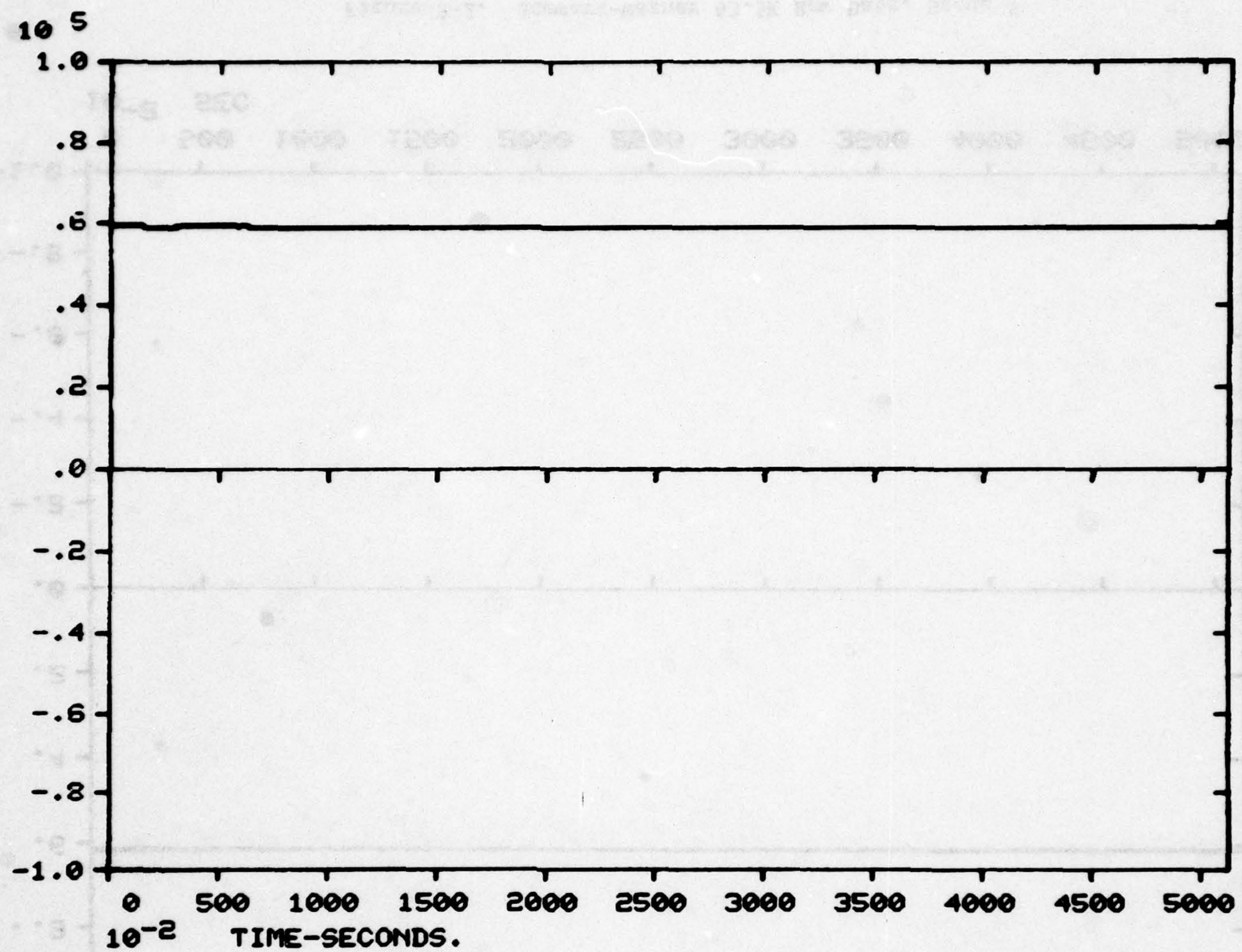


Figure B-3. Kollsman 63.5K Raw Data, Scene 4

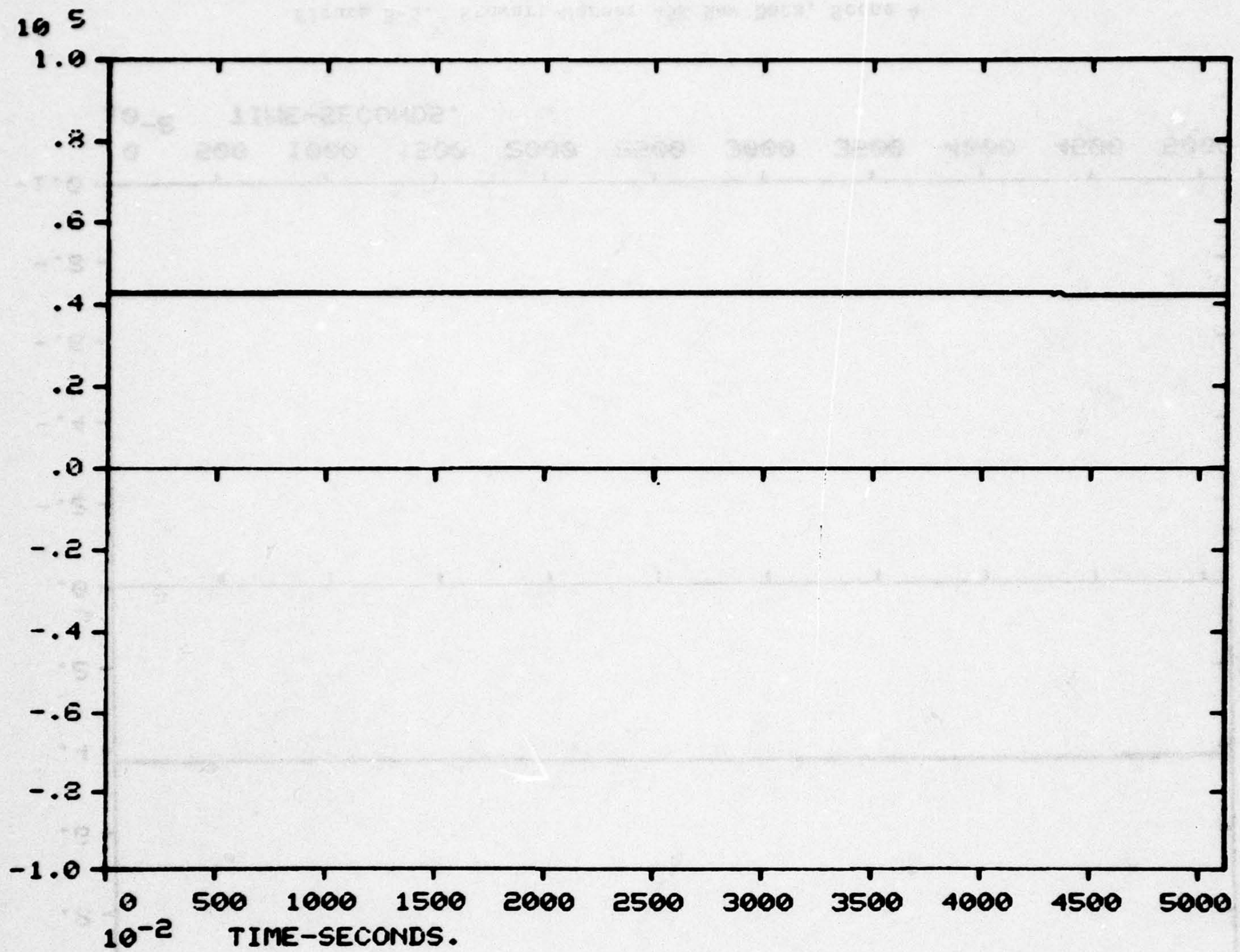


Figure B-4. Honeywell 45K Raw Data, Scene 4

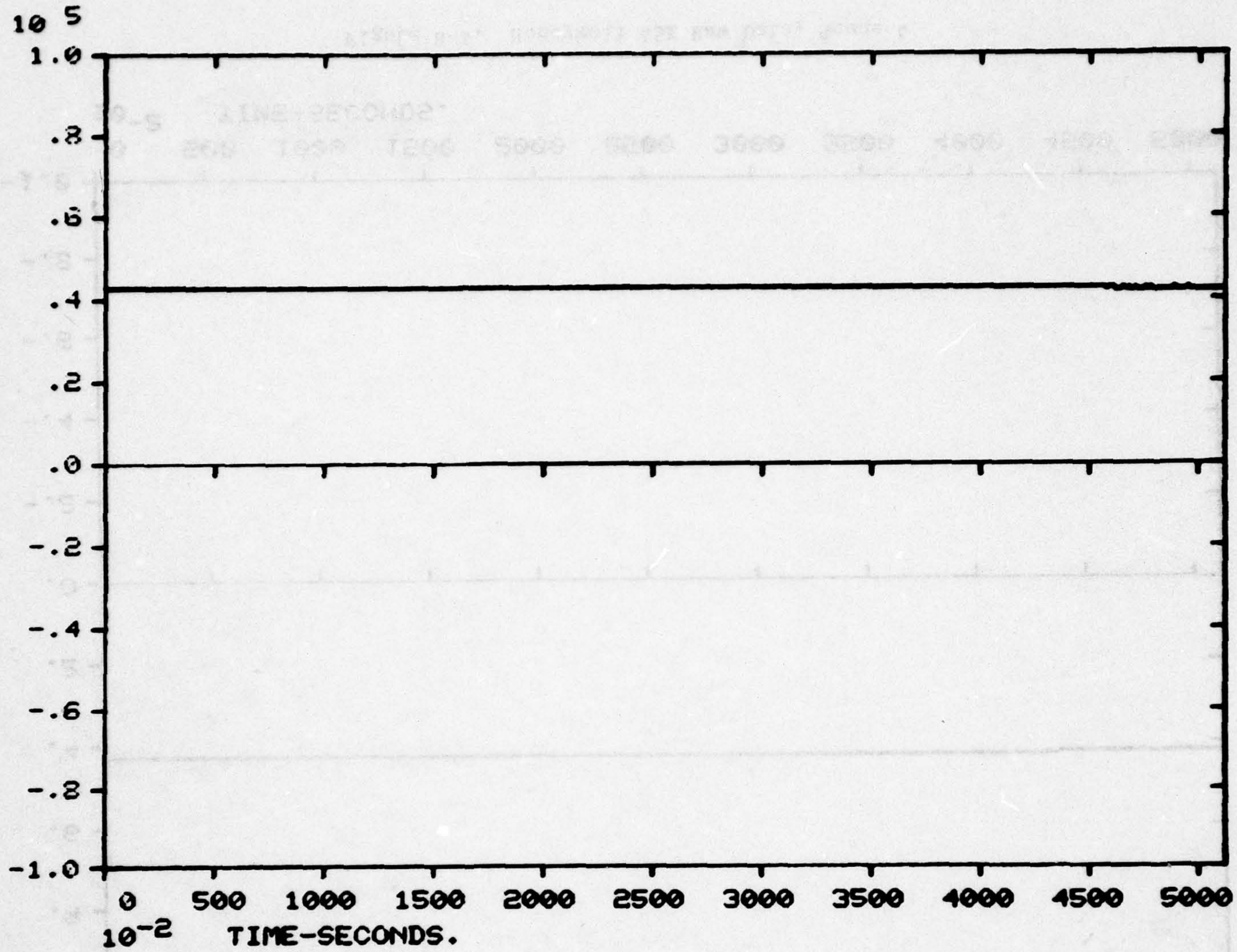


Figure B-5. Stewart-Warner 45K Raw Data, Scene 4

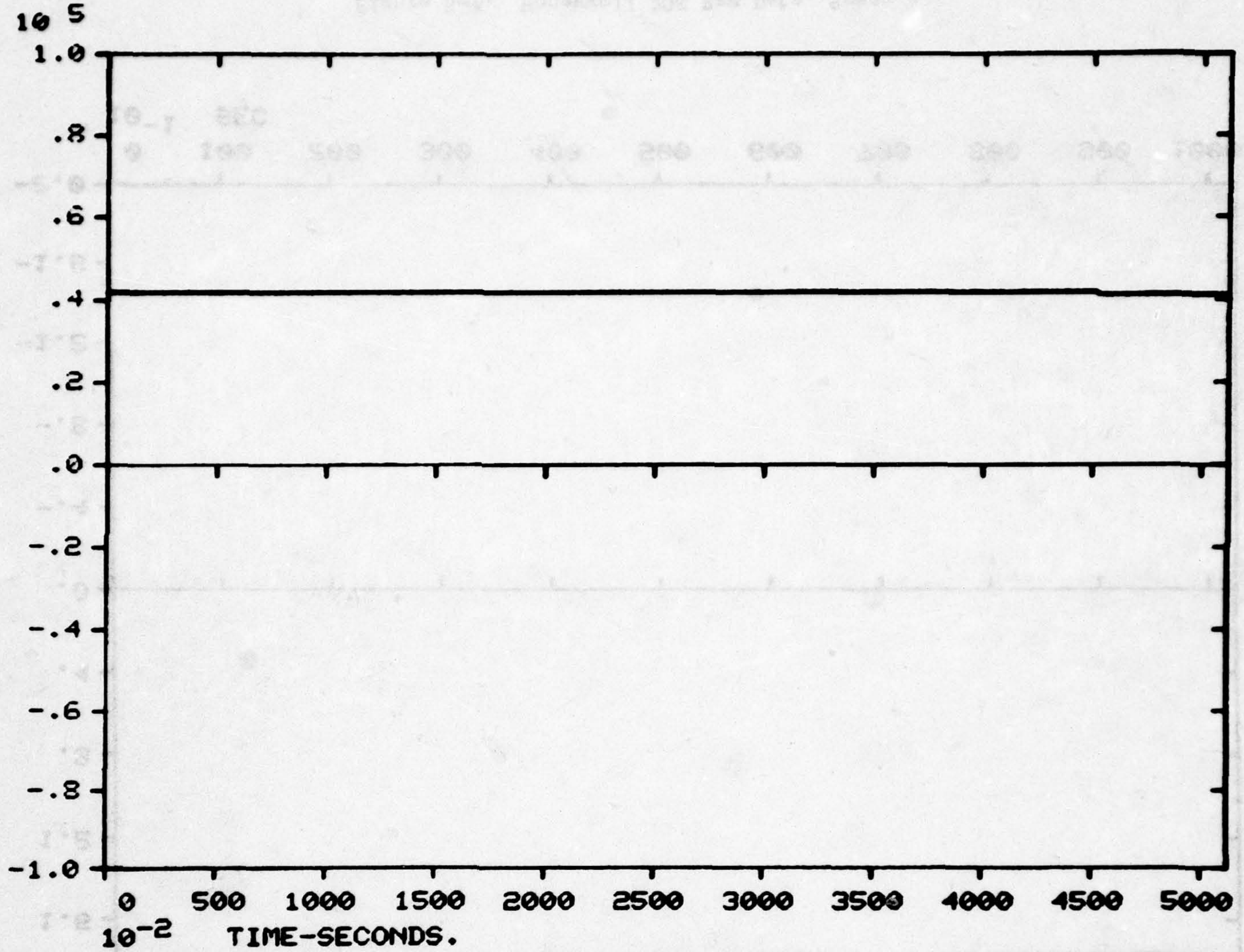


Figure B-6. Kollsman 45K Raw Data, Scene 4

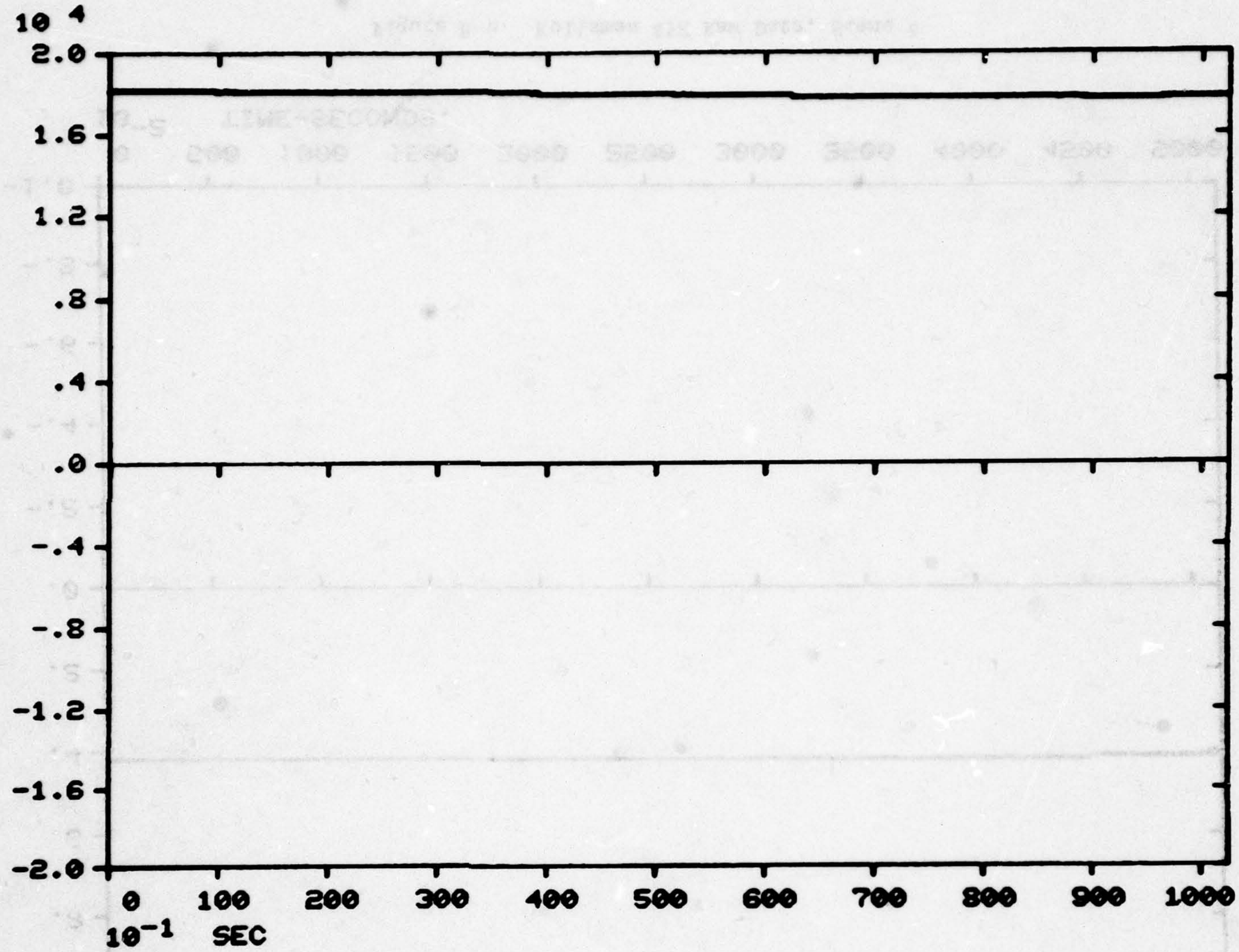


Figure B-7. Honeywell 20K Raw Data, Scene 4

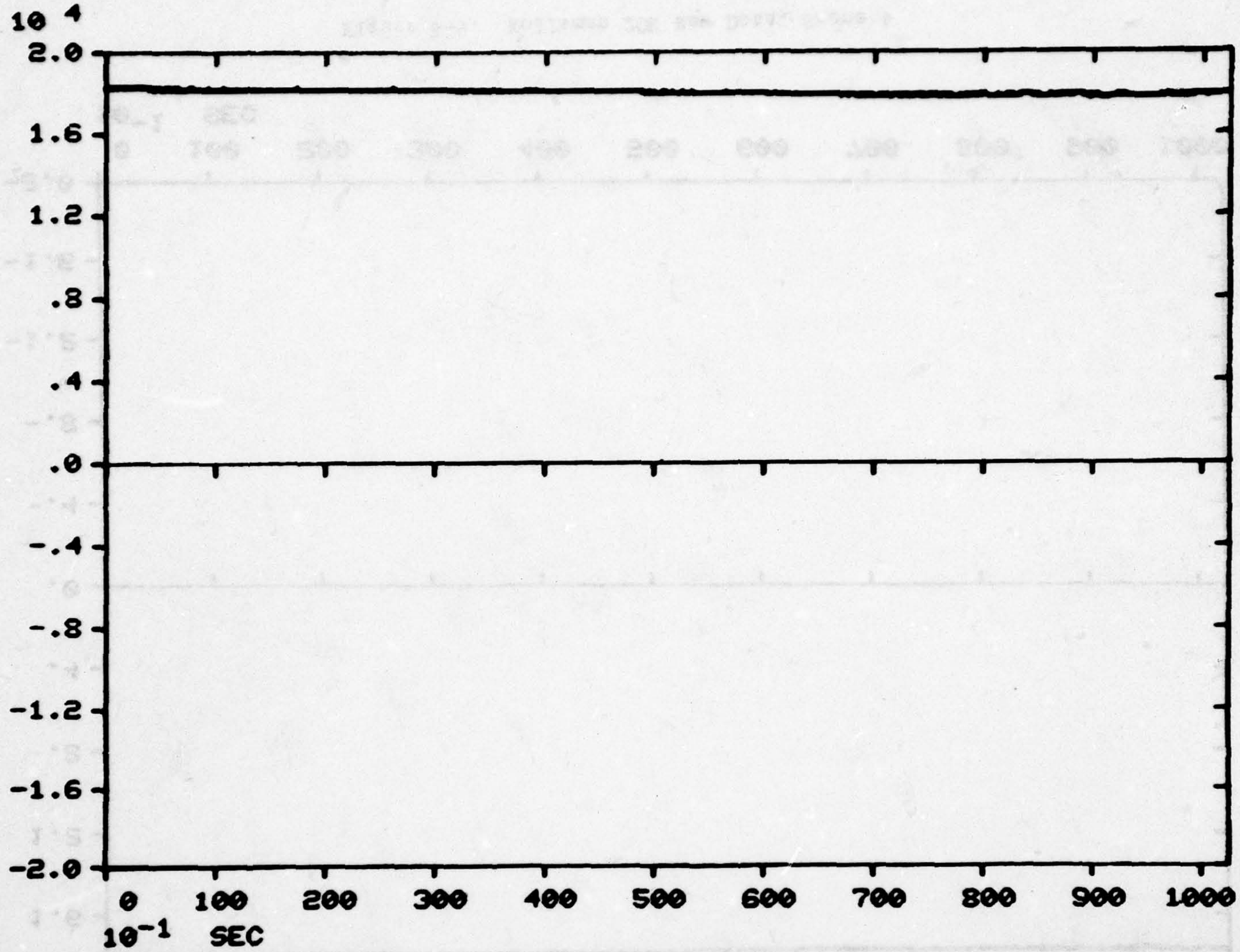


Figure B-8. Stewart-Warner 20K Raw Data, Scene 4

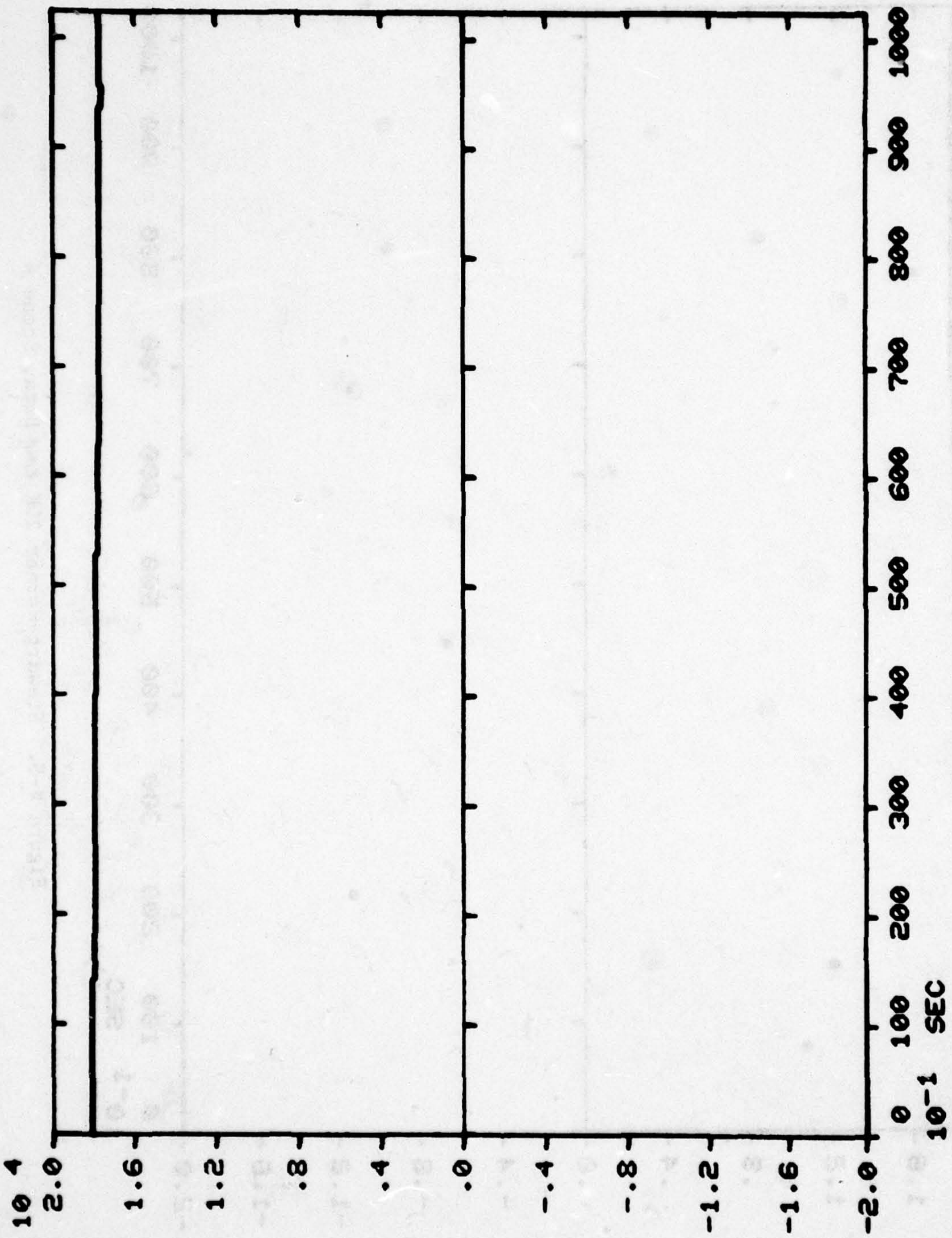


Figure B-9. Kollsman 20K Raw Data, Scene 4

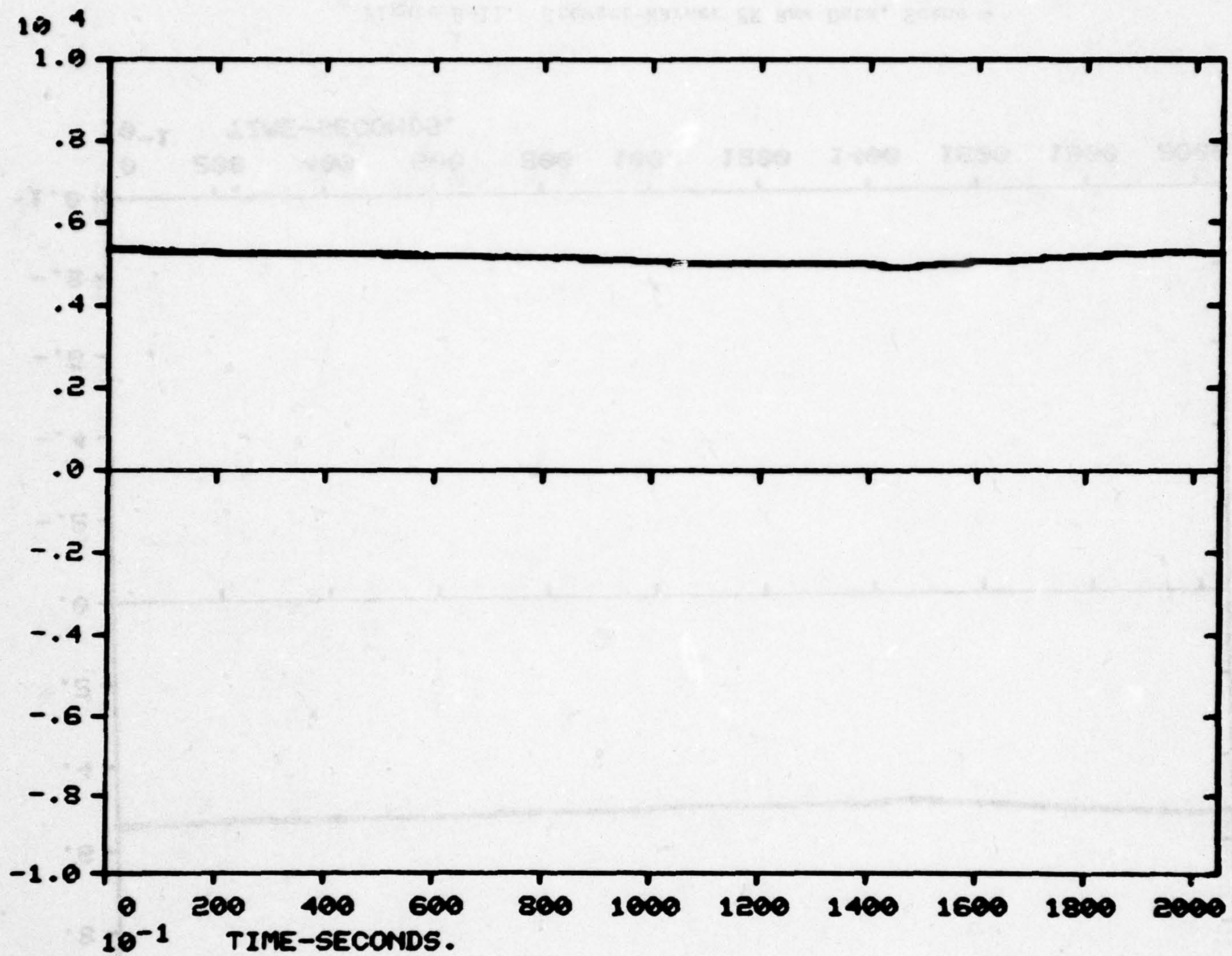


Figure B-10. Honeywell 8K Raw Data, Scene 4

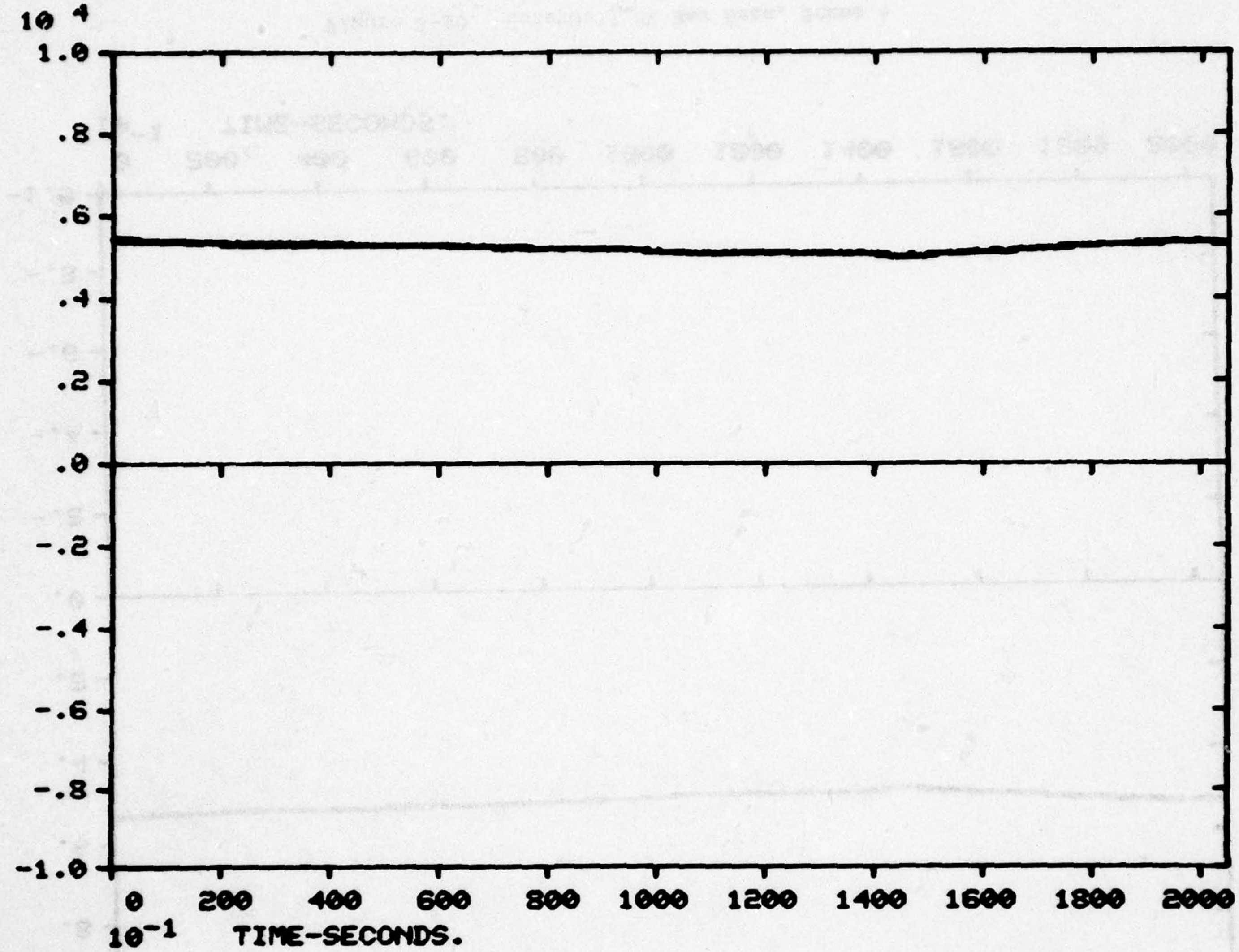


Figure B-11. Stewart-Warner 8K Raw Data, Scene 4

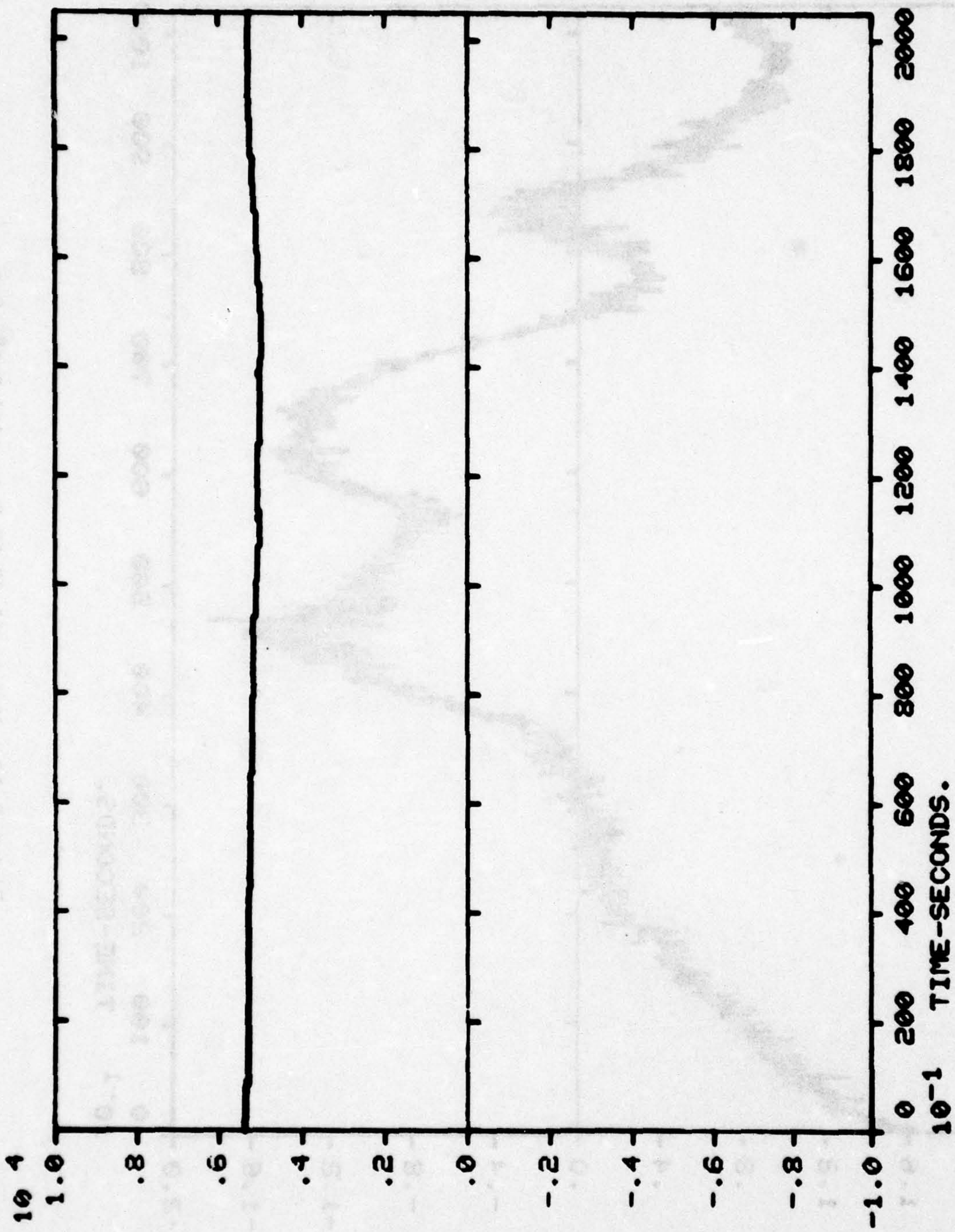


Figure B-12. Kollsman 8K Raw Data, Scene 4

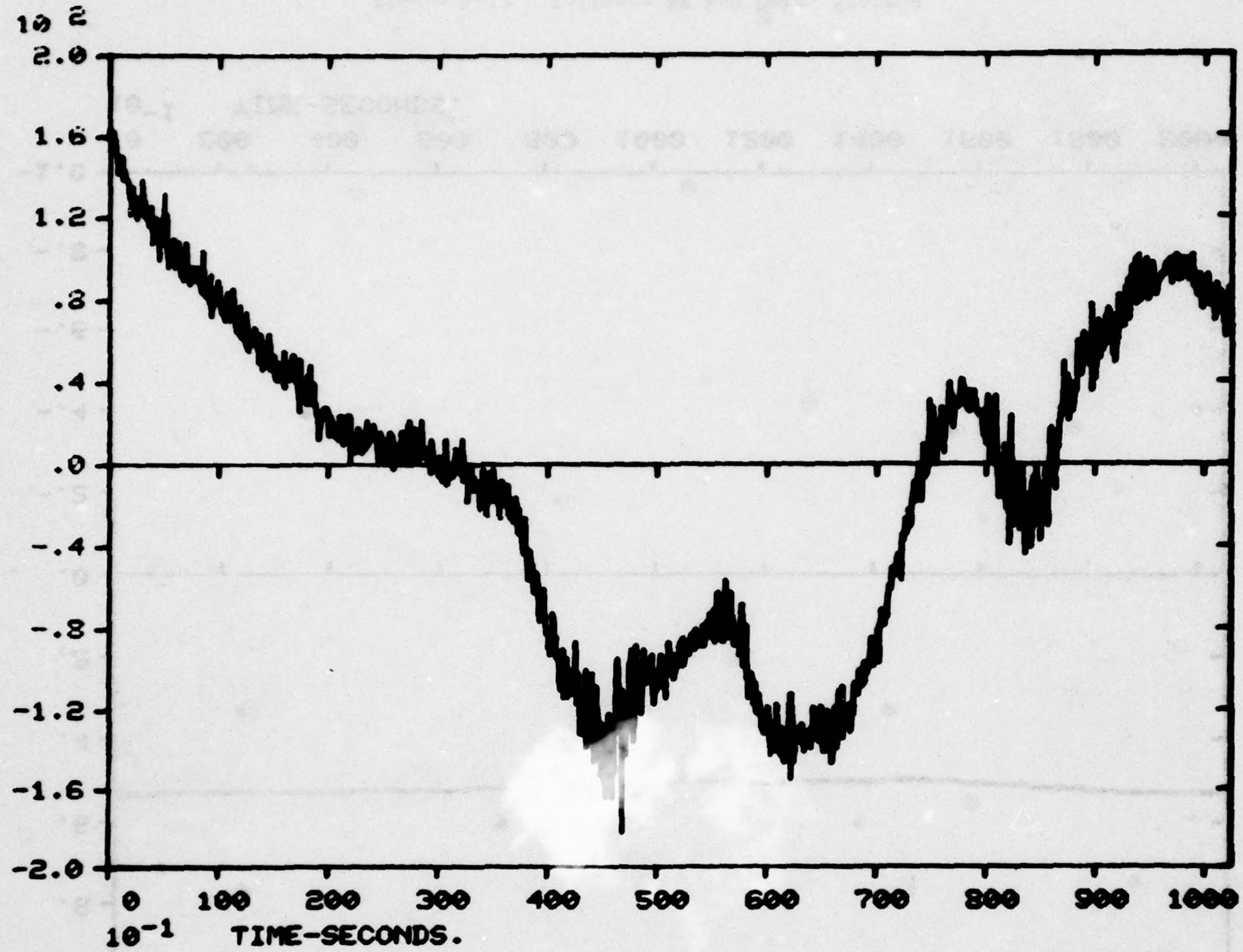


Figure B-13. Honeywell 63.5K Detrended Data, Scene 4

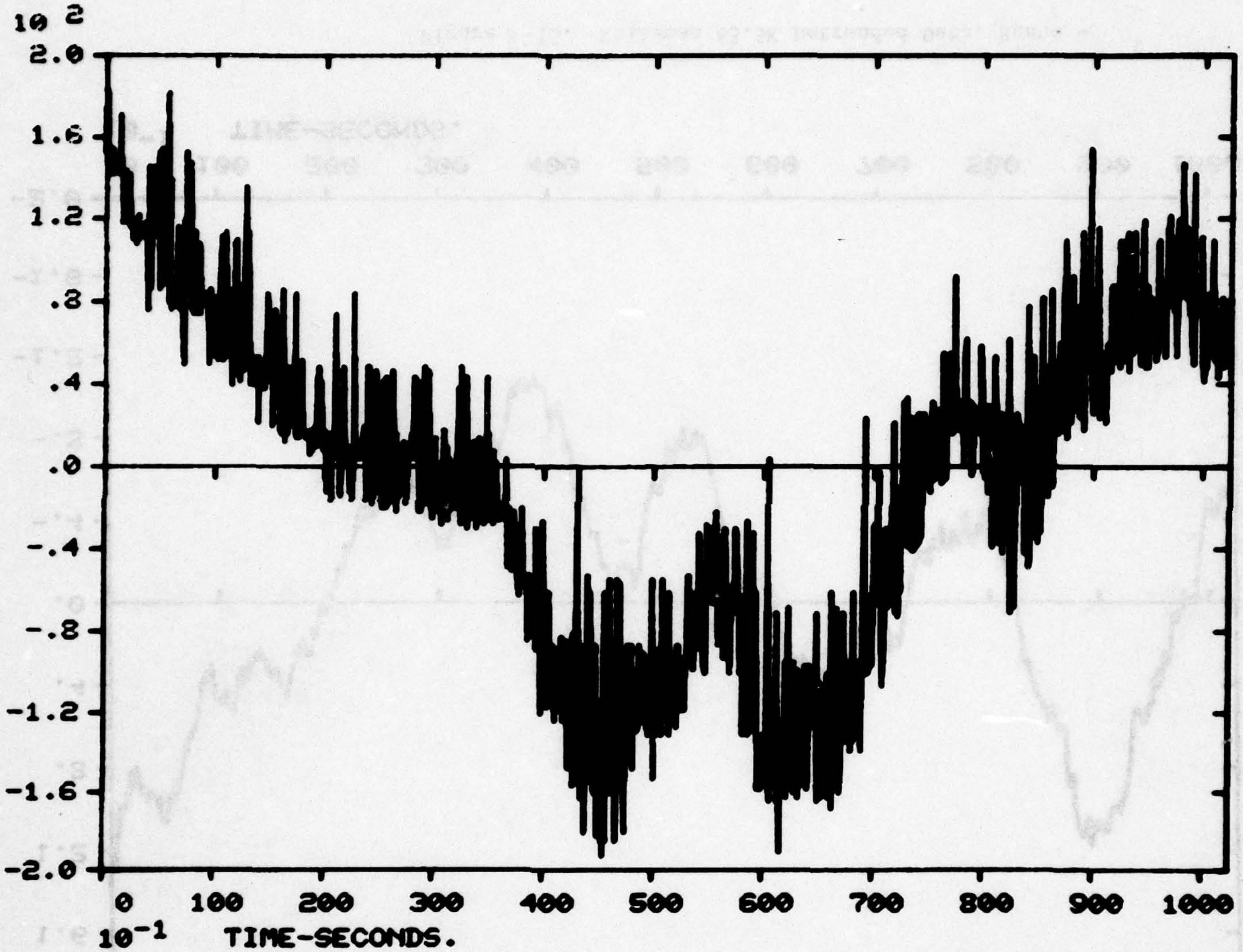


Figure B-14. Stewart-Warner 63.5K Detrended Data, Scene 4

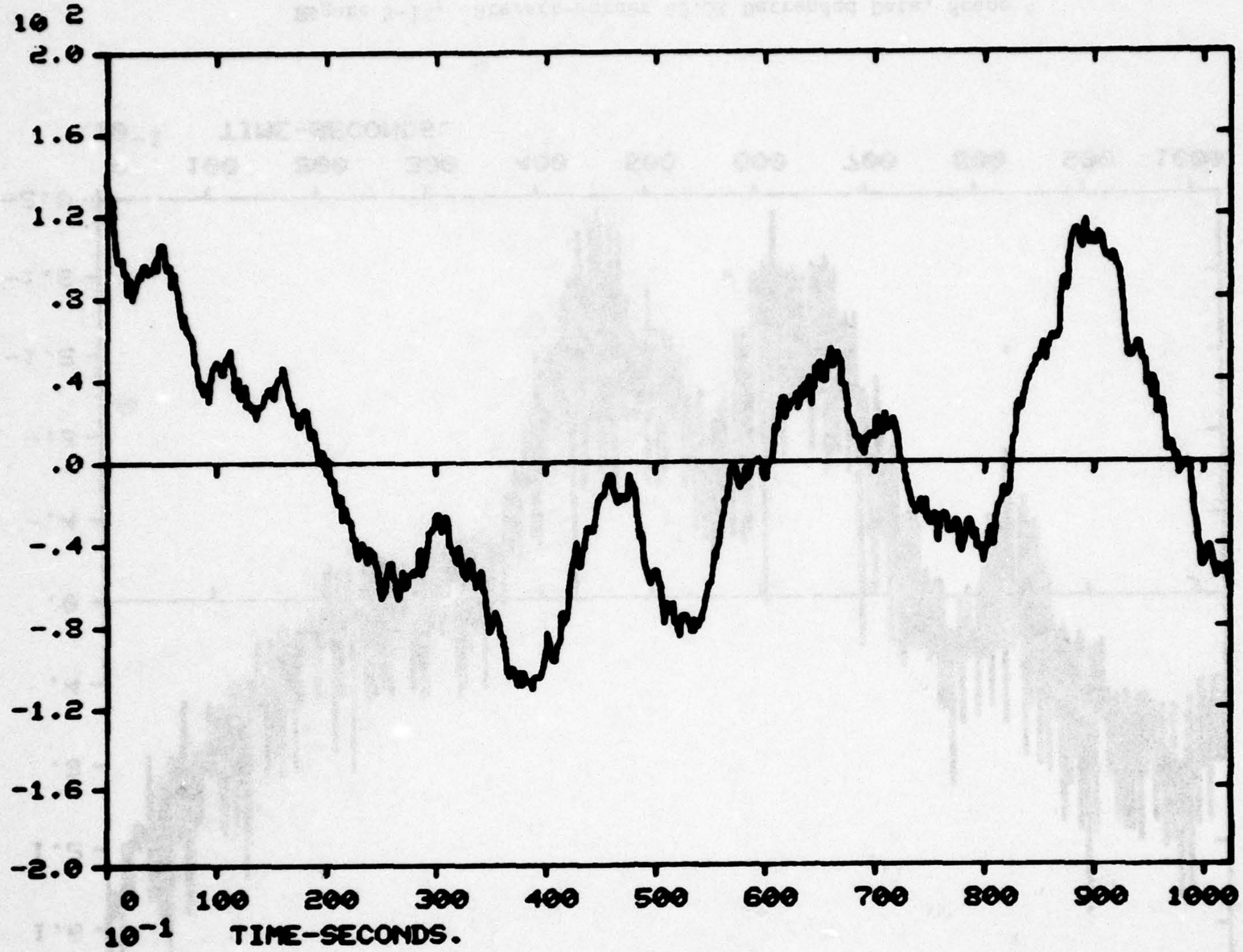


Figure B-15. Kollsman 63.5K Detrended Data, Scene 4

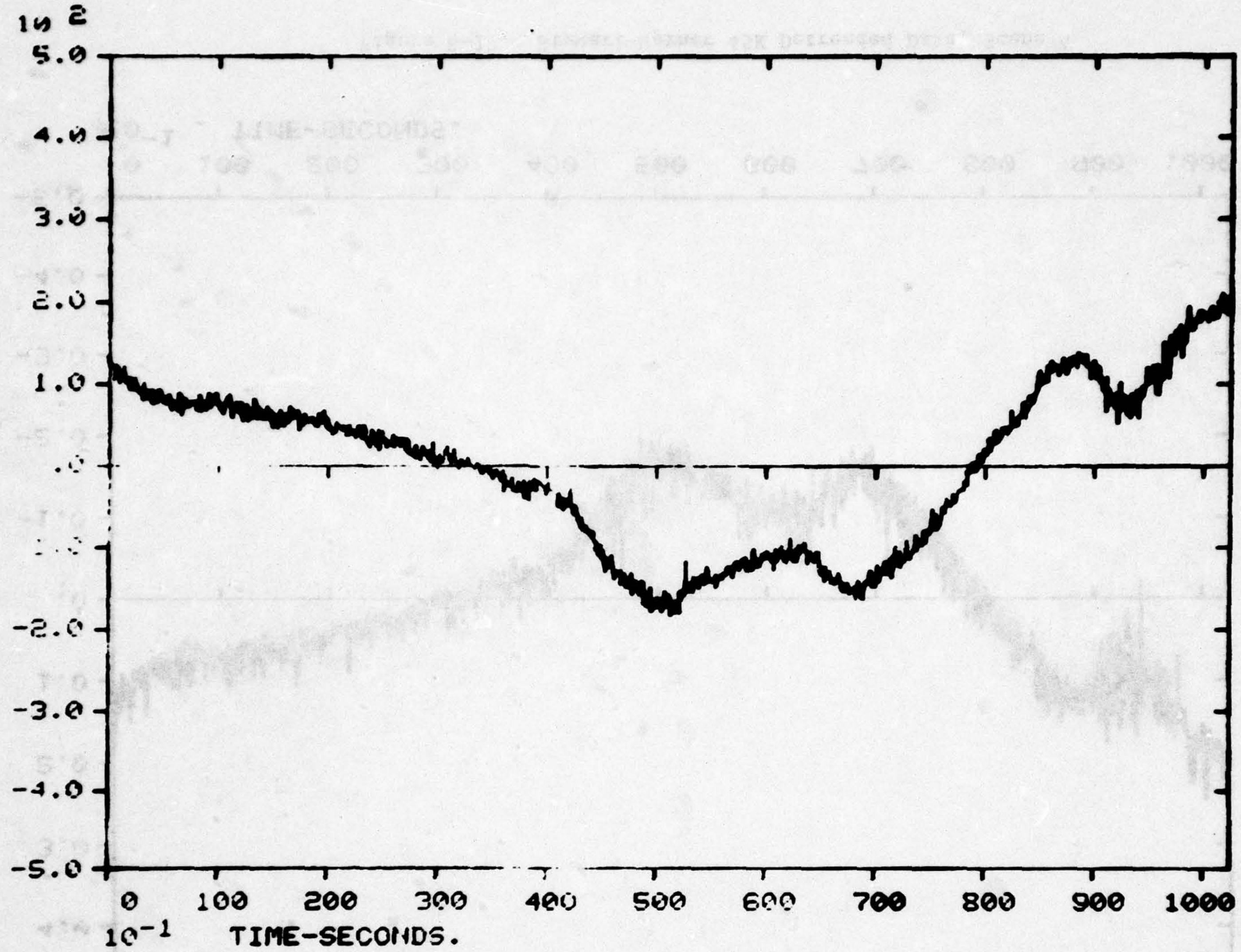


Figure B-16. Honeywell 45K Detrended Data, Scene 4

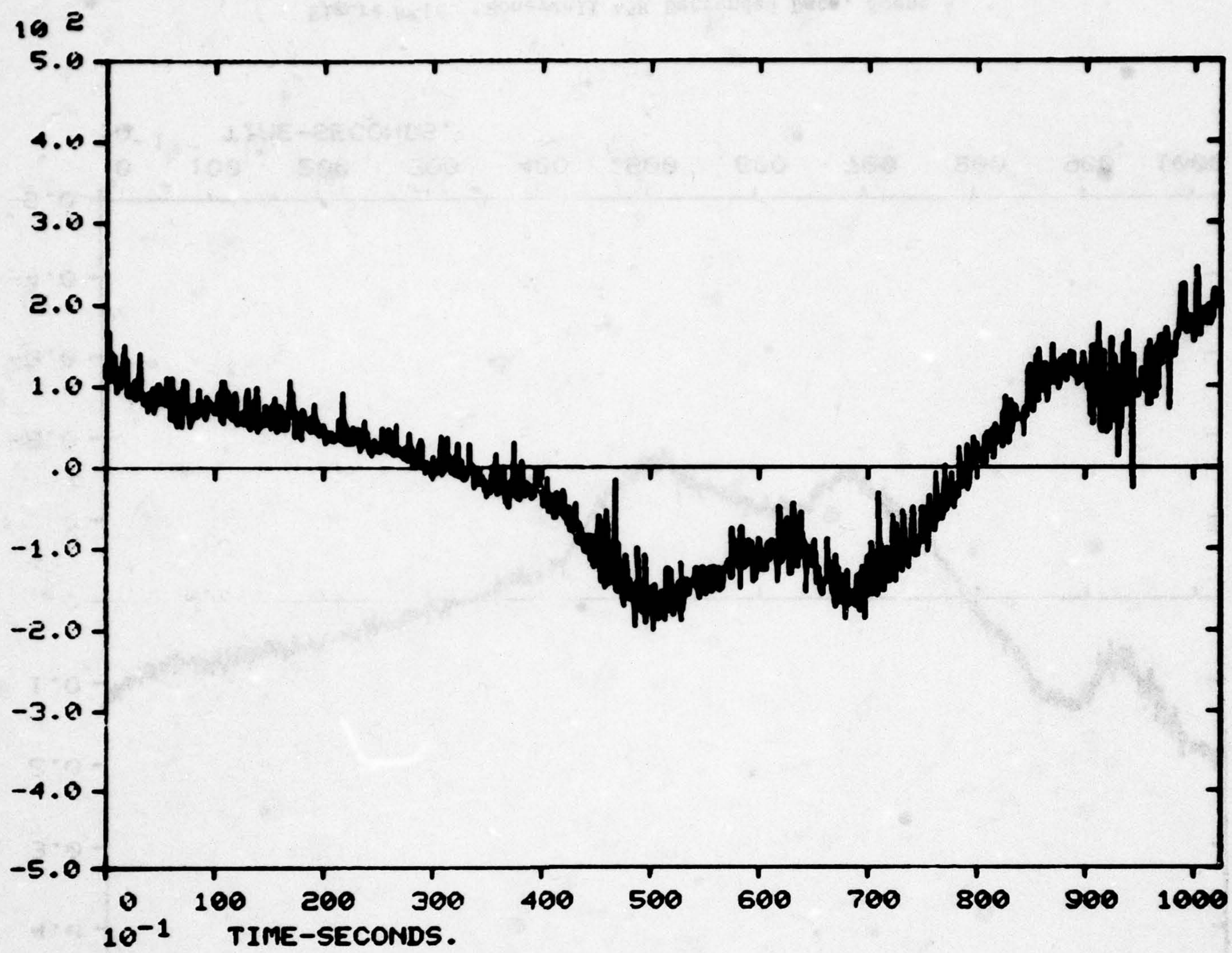


Figure B-17. Stewart-Warner 45K Detrended Data, Scene 4

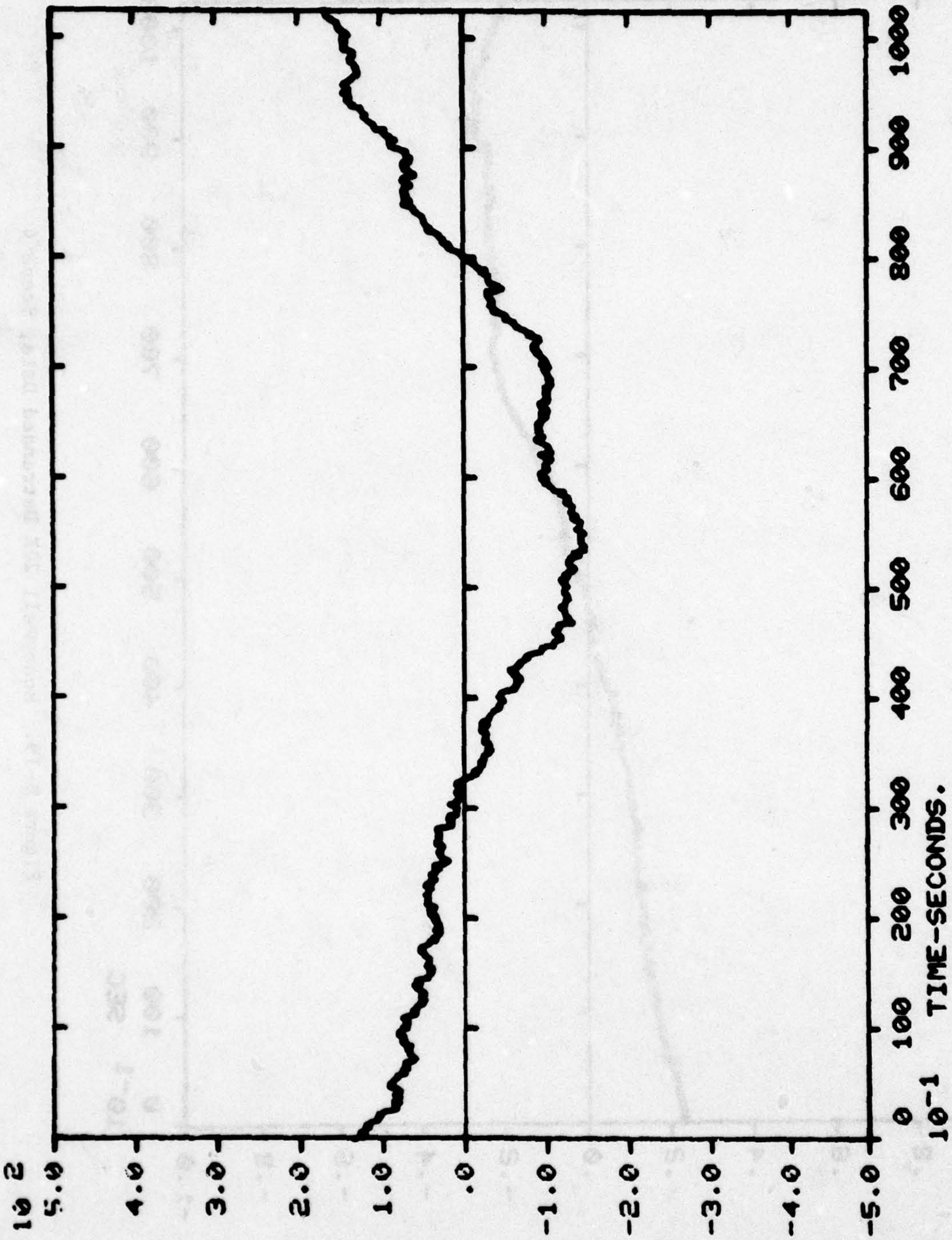


Figure B-18. Kollsman 45K Detrended Data, Scene 4

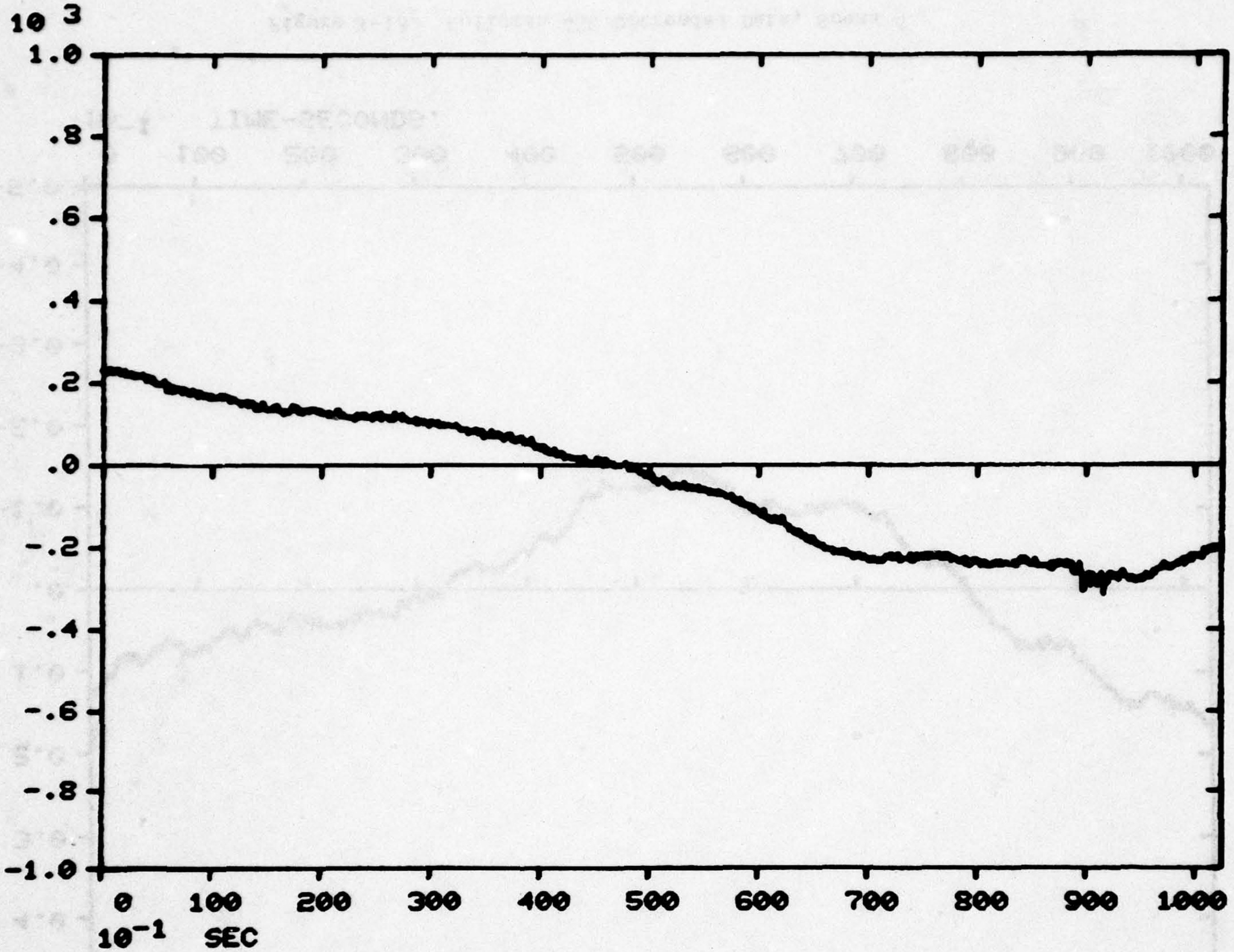


Figure B-19. Honeywell 20K Detrended Data, Scene 4

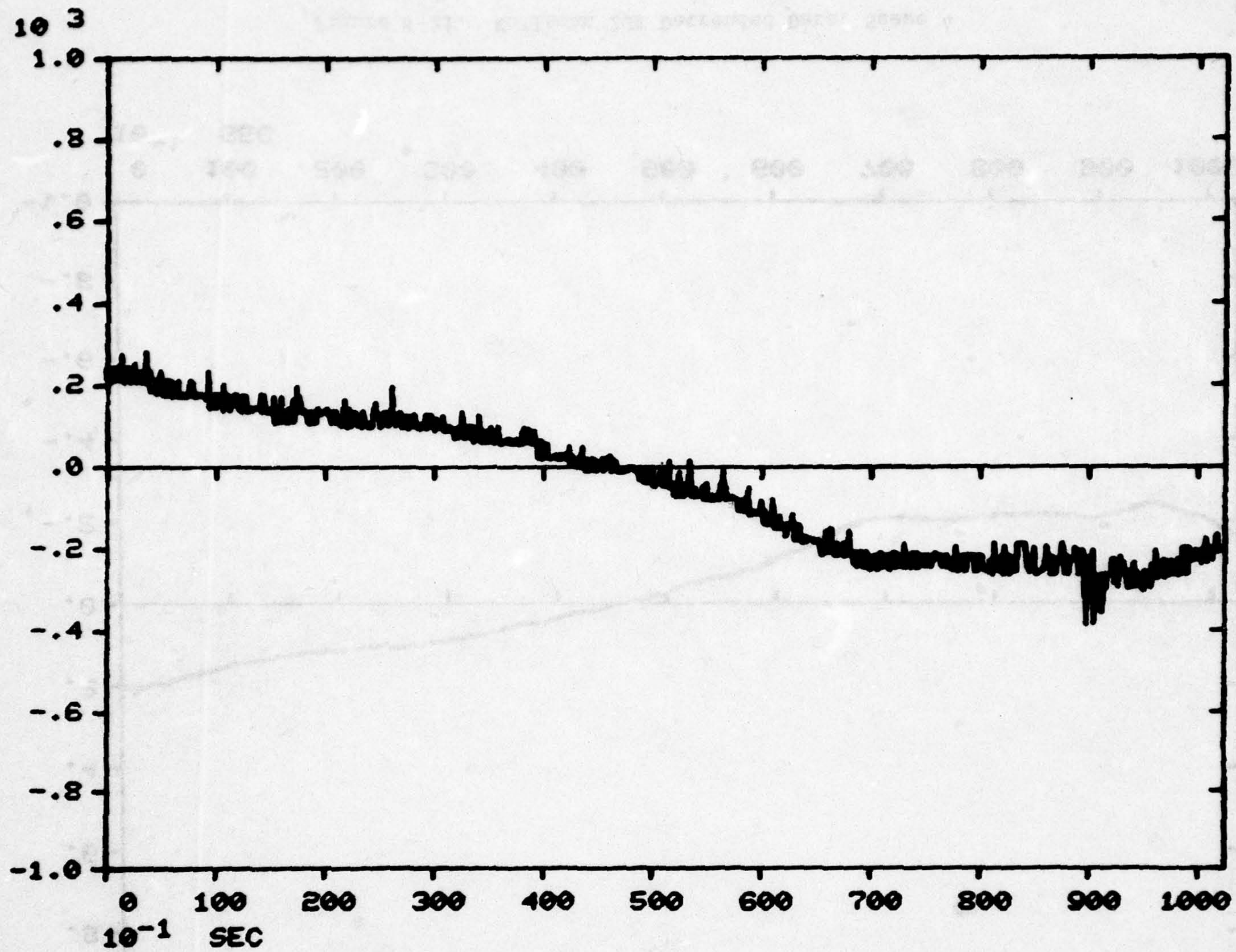


Figure B-20. Stewart-Warner 20K Detrended Data, Scene 4

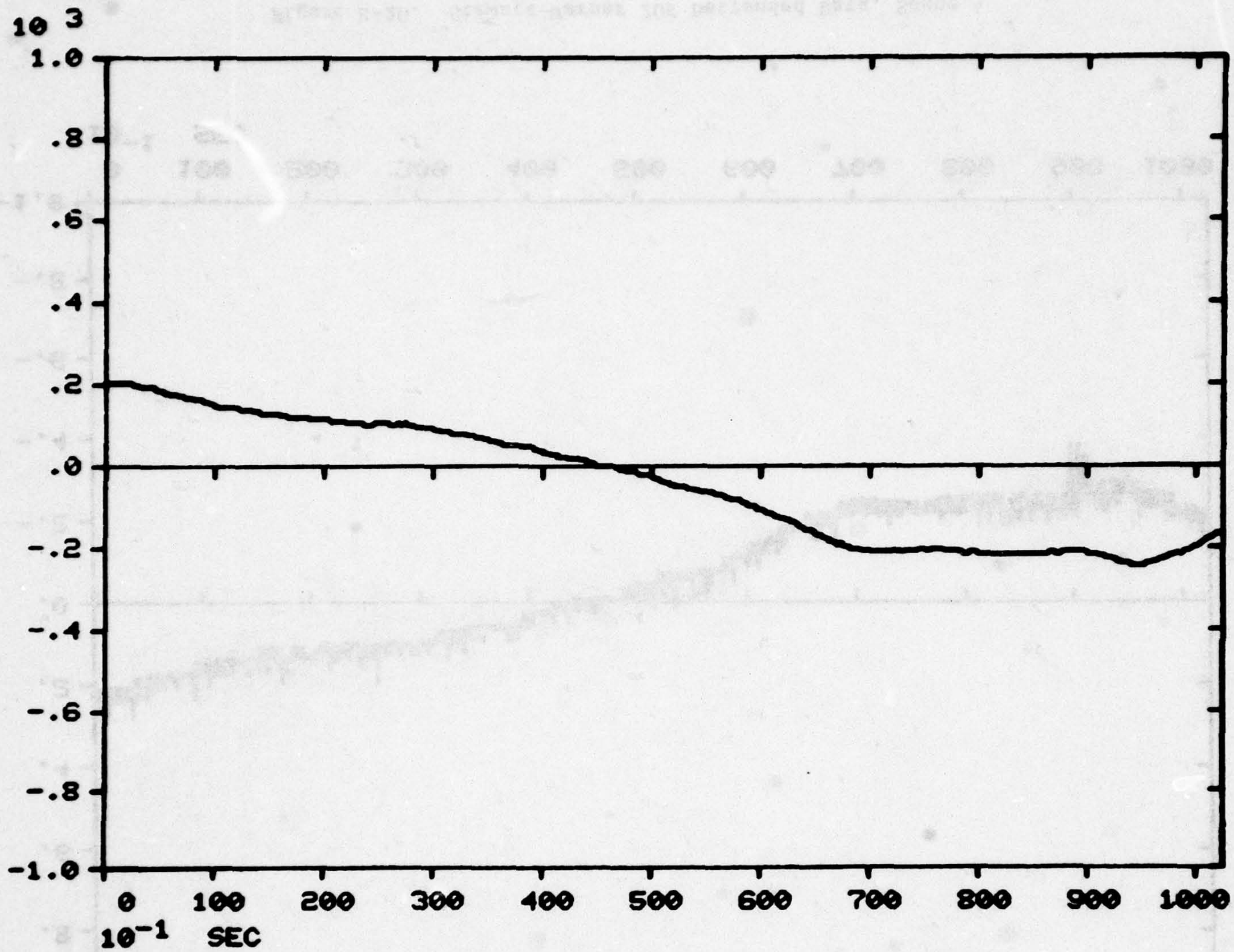


Figure B-21. Kollsman 20K Detrended Data, Scene 4

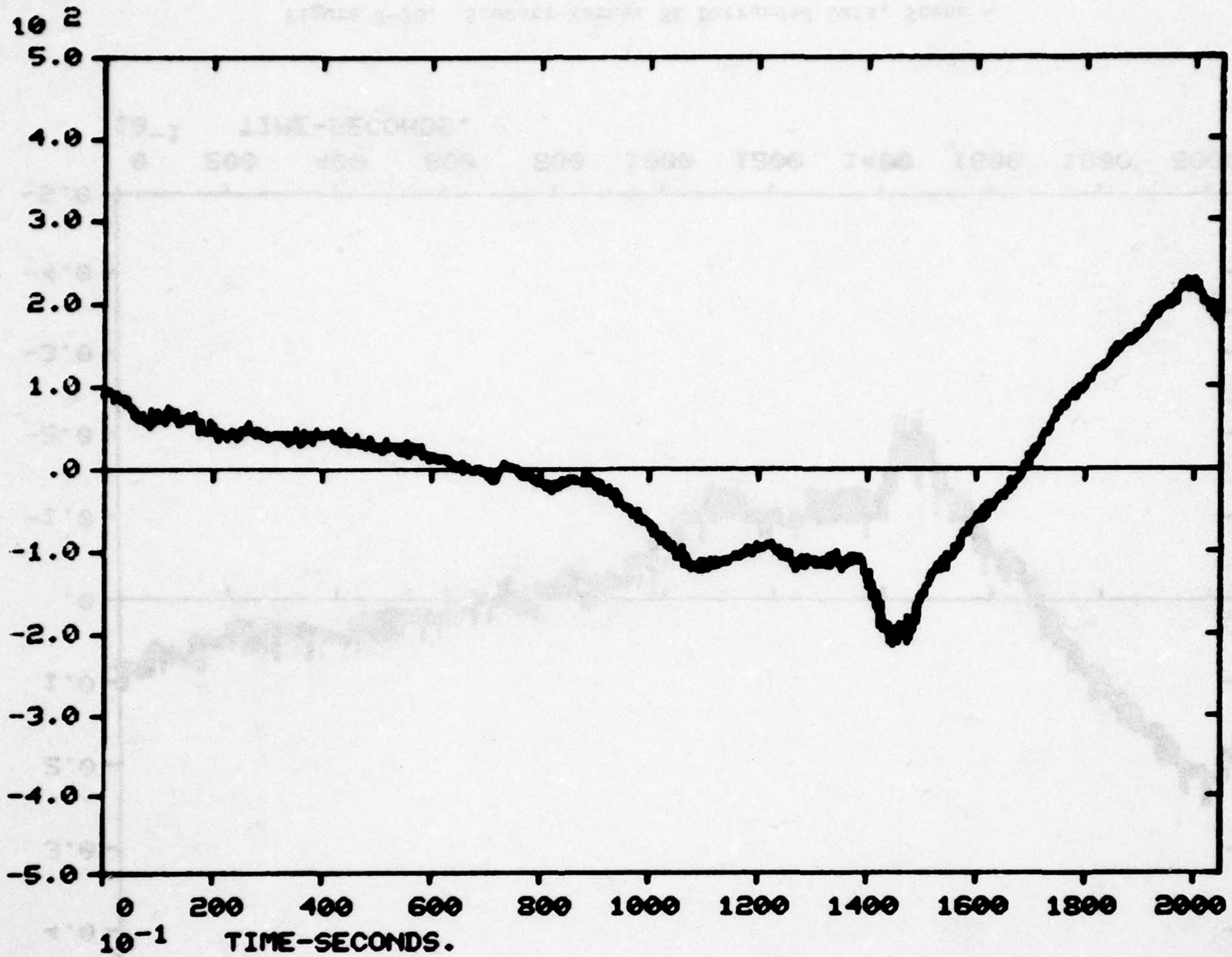


Figure B-22. Honeywell 8K Detrended Data, Scene 4

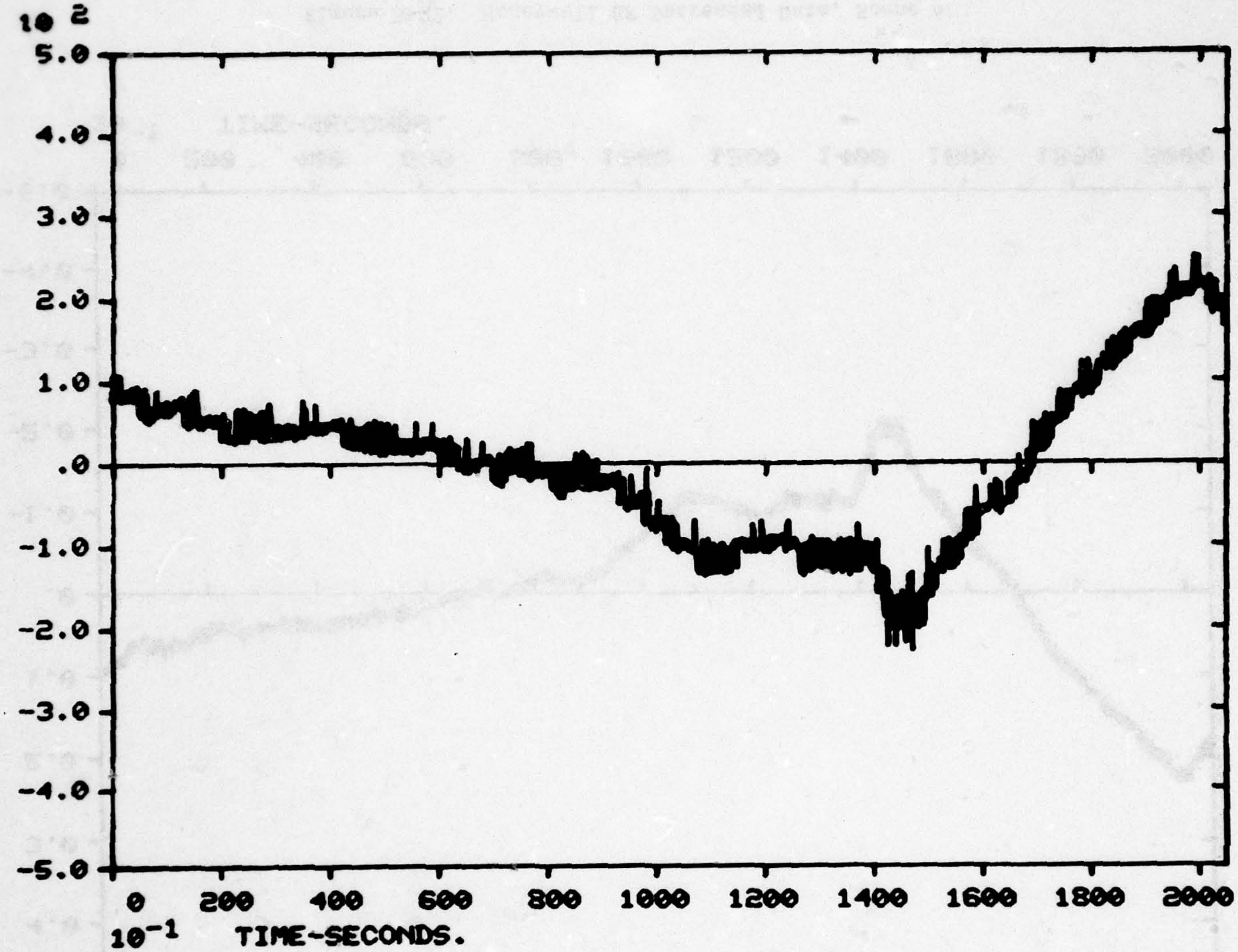


Figure B-23. Stewart-Warner 8K Detrended Data, Scene 4

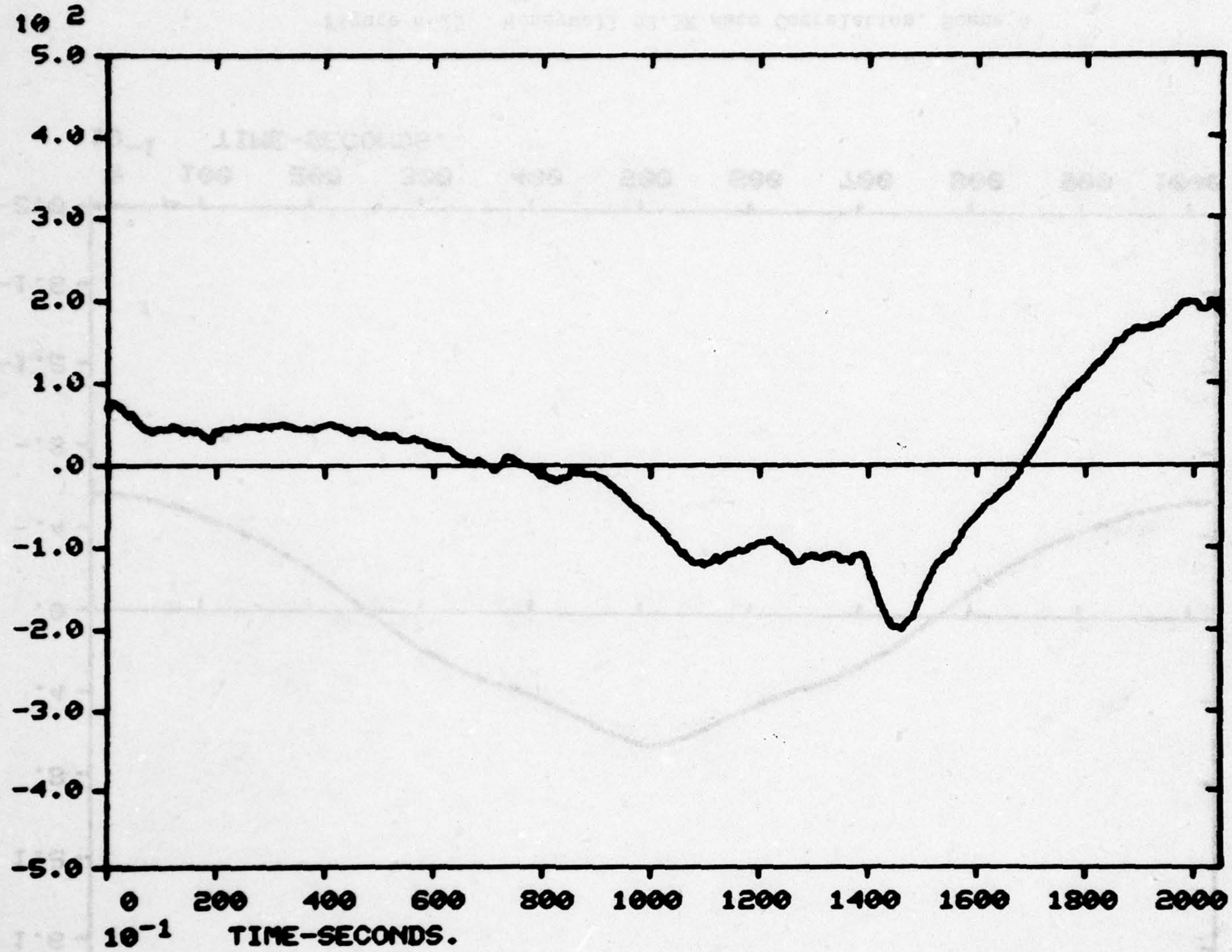


Figure B-24. Kollsman 8K Detrended Data, Scene 4

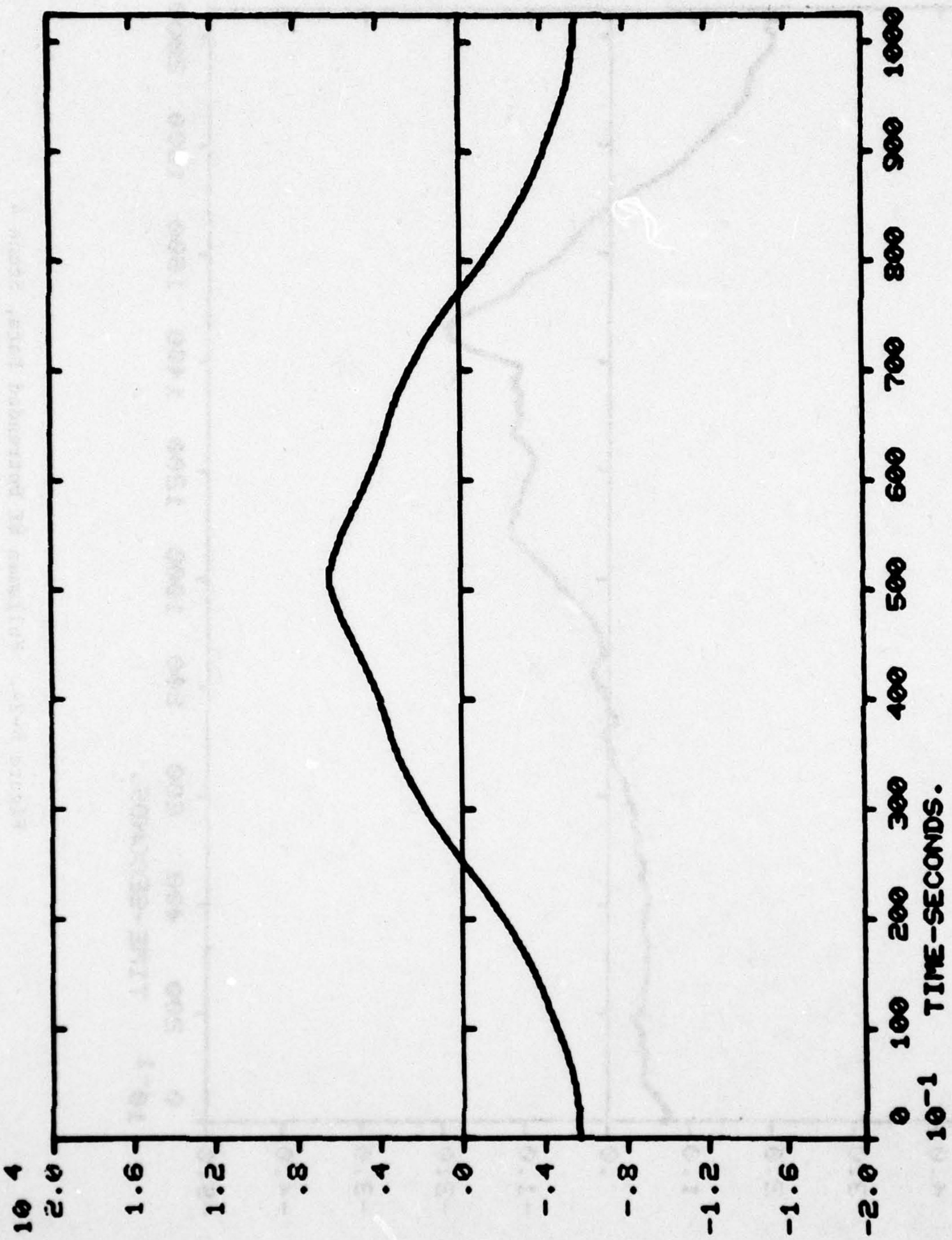


Figure B-25. Honeywell 63.5K Auto Correlation, Scene 4

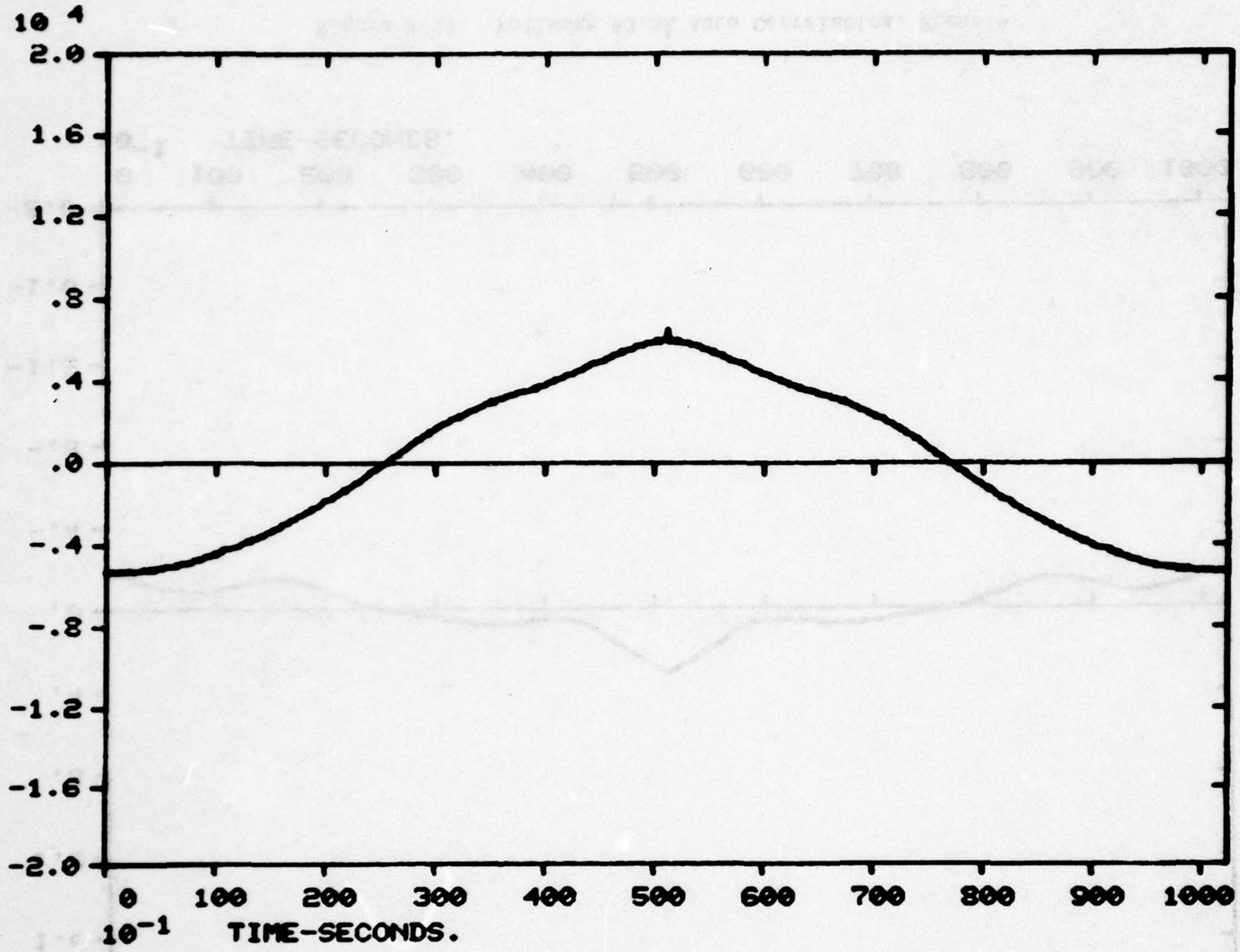


Figure B-26. Stewart-Warner 63.5K Auto Correlation, Scene 4

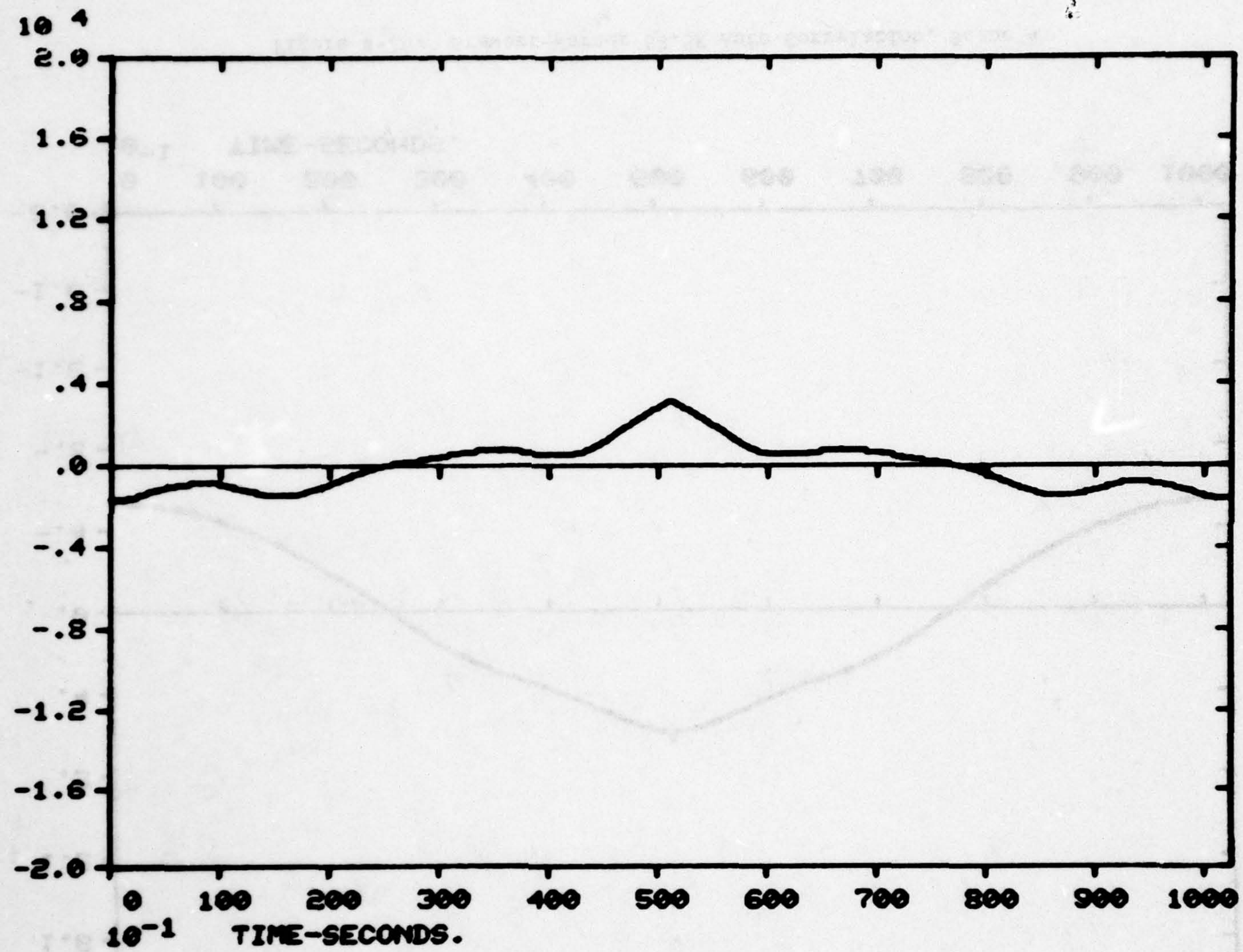


Figure B-27. Kollsman 63.5K Auto Correlation, Scene 4

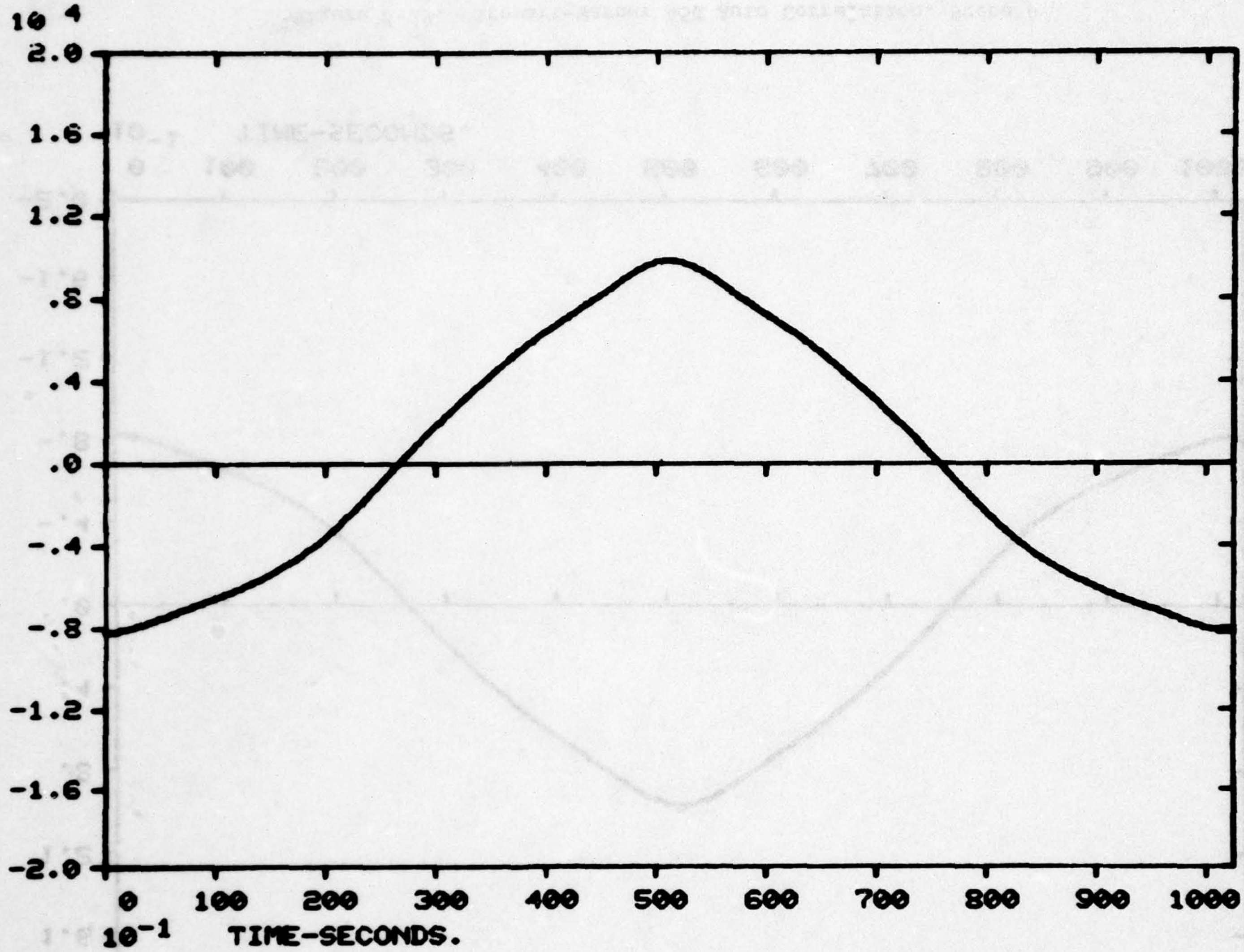


Figure B-28. Honeywell 45K Auto Correlation, Scene 4

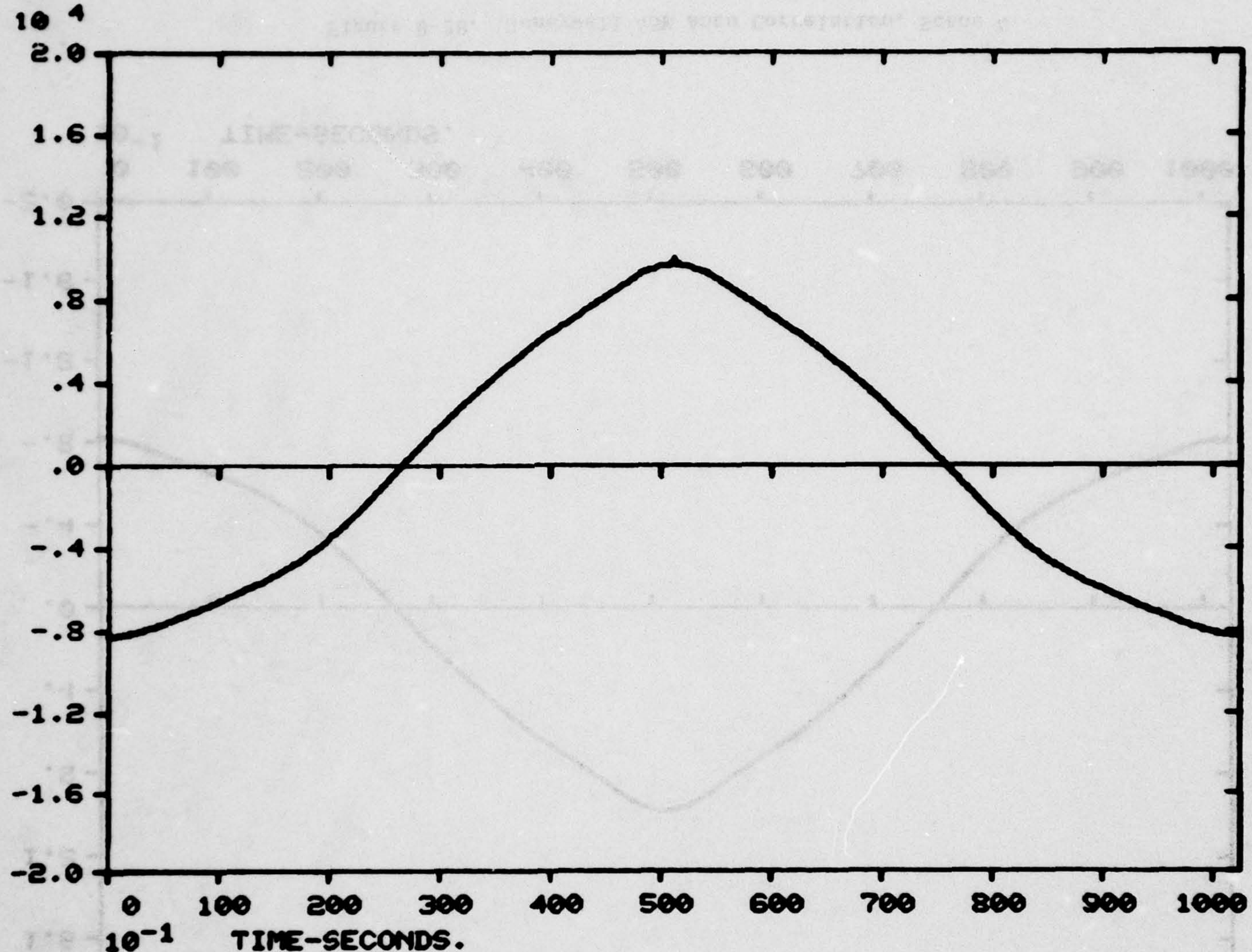


Figure B-29. Stewart-Warner 45K Auto Correlation, Scene 4

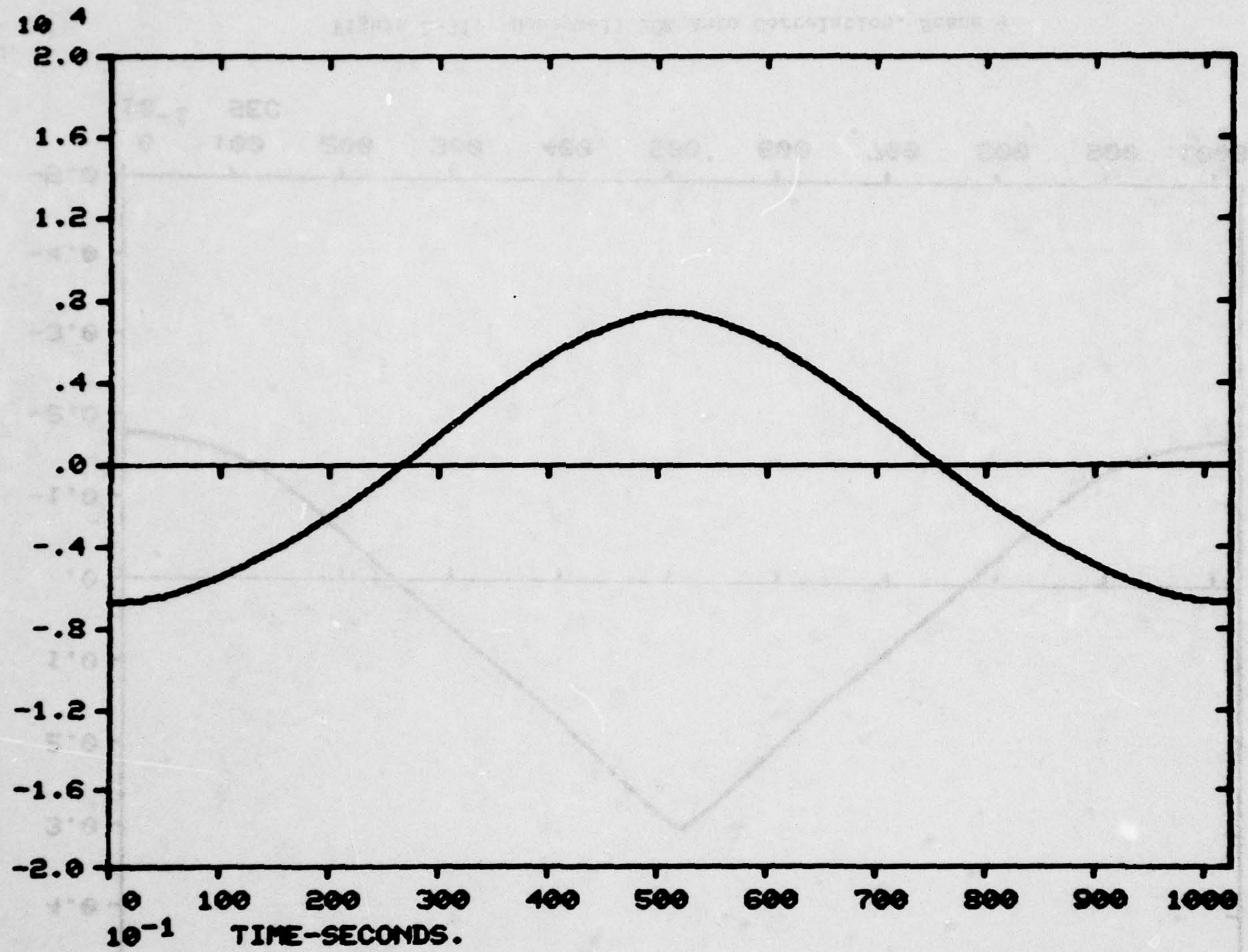


Figure B-30. Kollsman 45K Auto Correlation, Scene 4

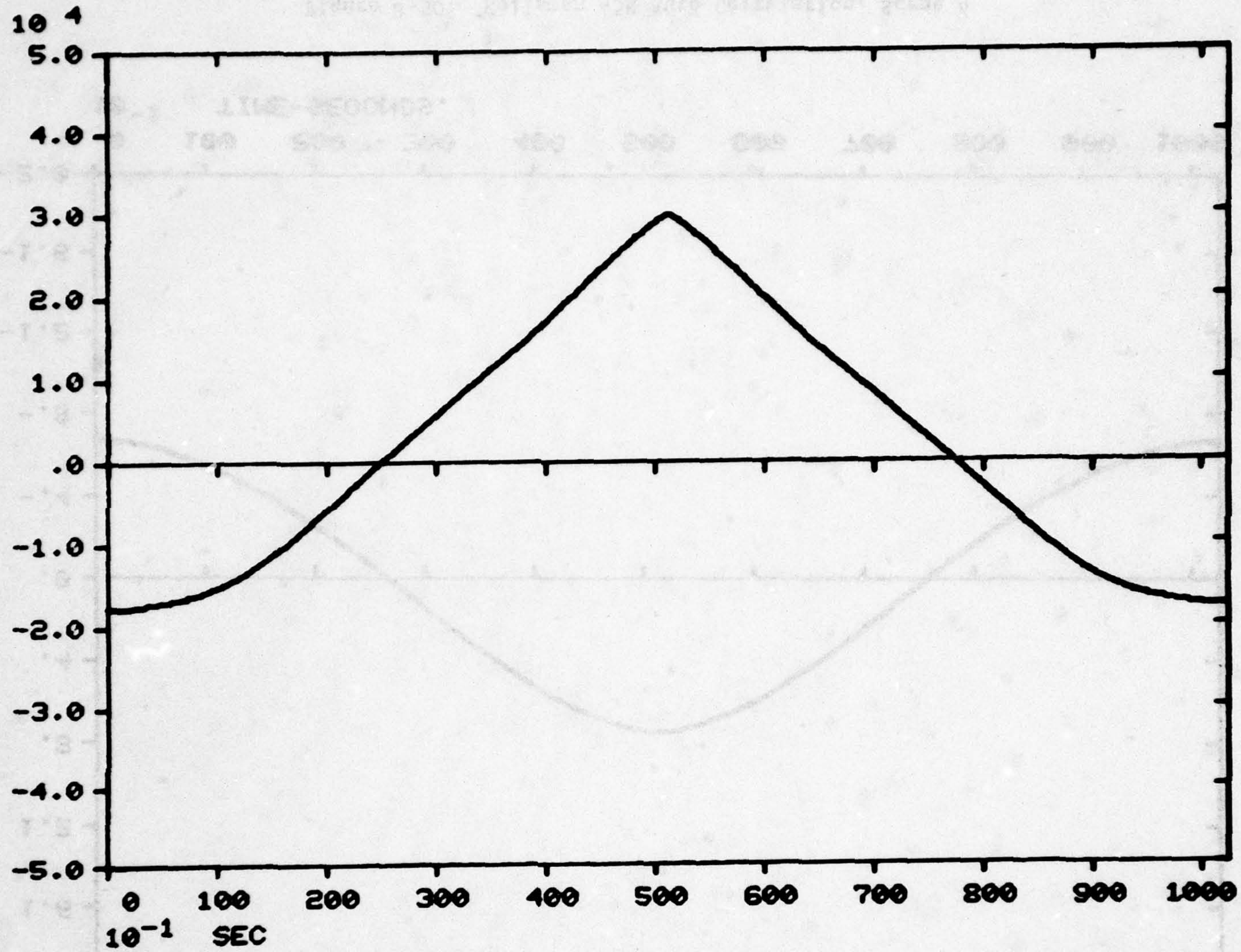


Figure B-31. Honeywell 20K Auto Correlation, Scene 4

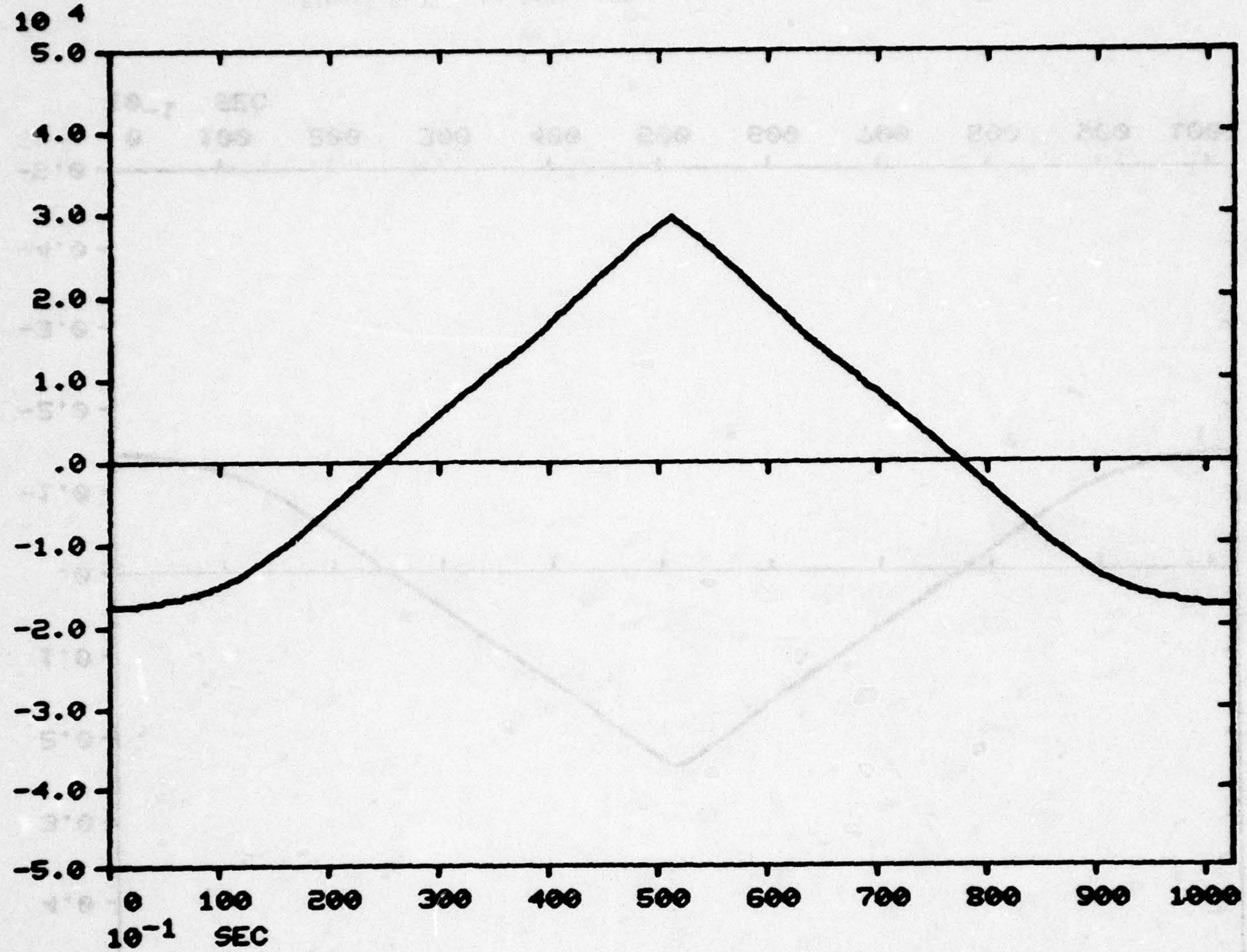


Figure B-32. Stewart-Warner 20K Auto Correlation, Scene 4

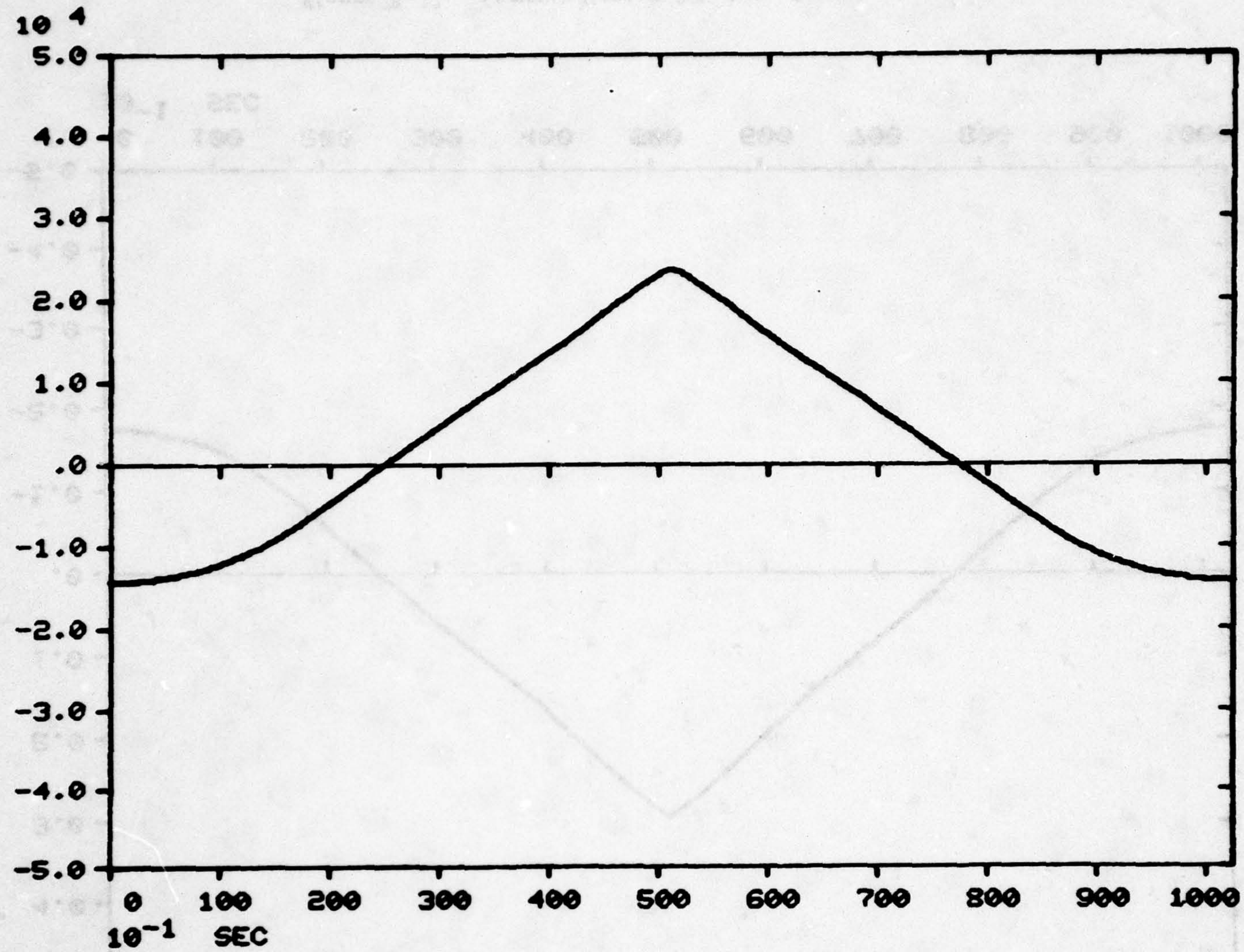


Figure B-33. Kollsman 20K Auto Correlation, Scene 4

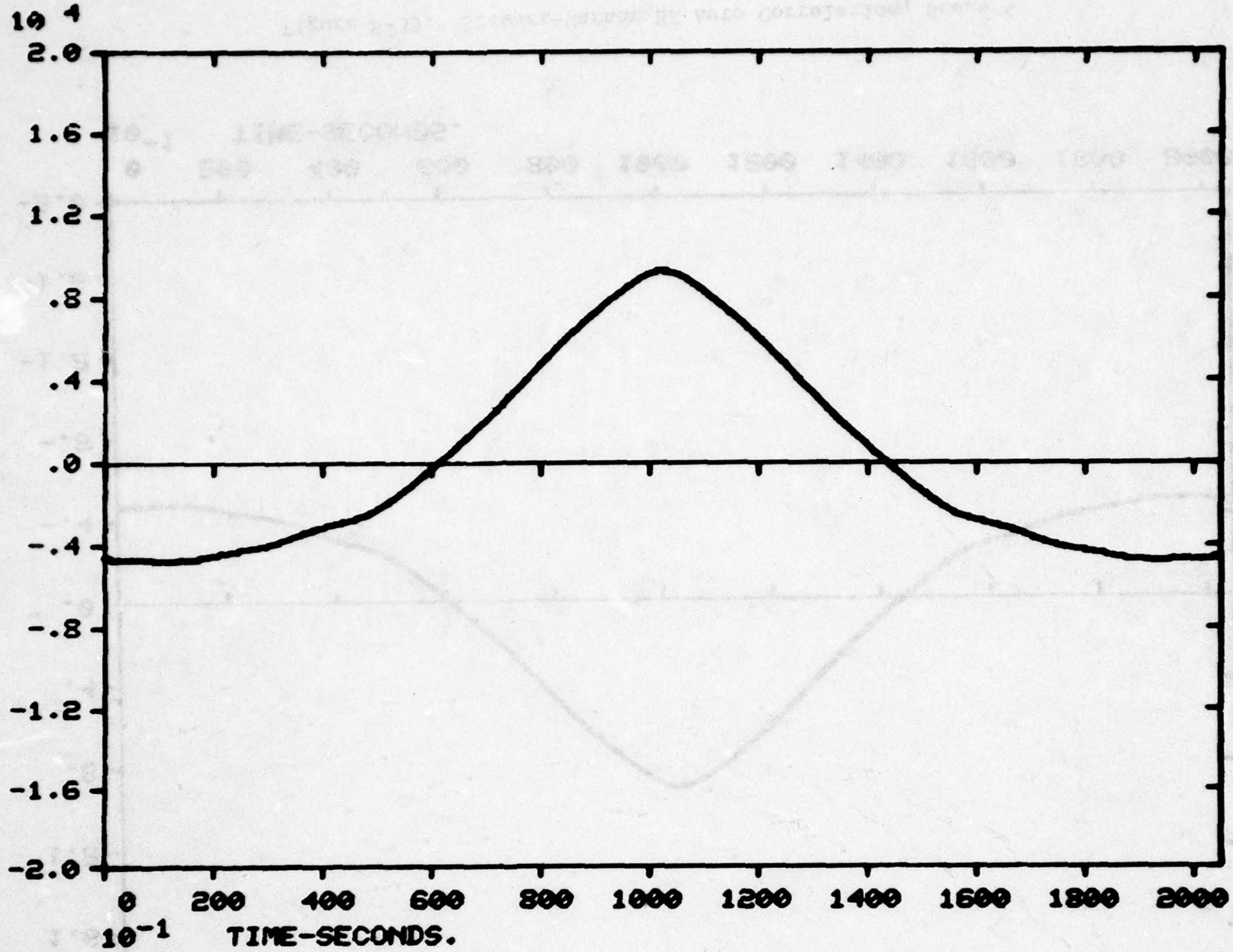


Figure B-34. Honeywell 8K Auto Correlation, Scene 4

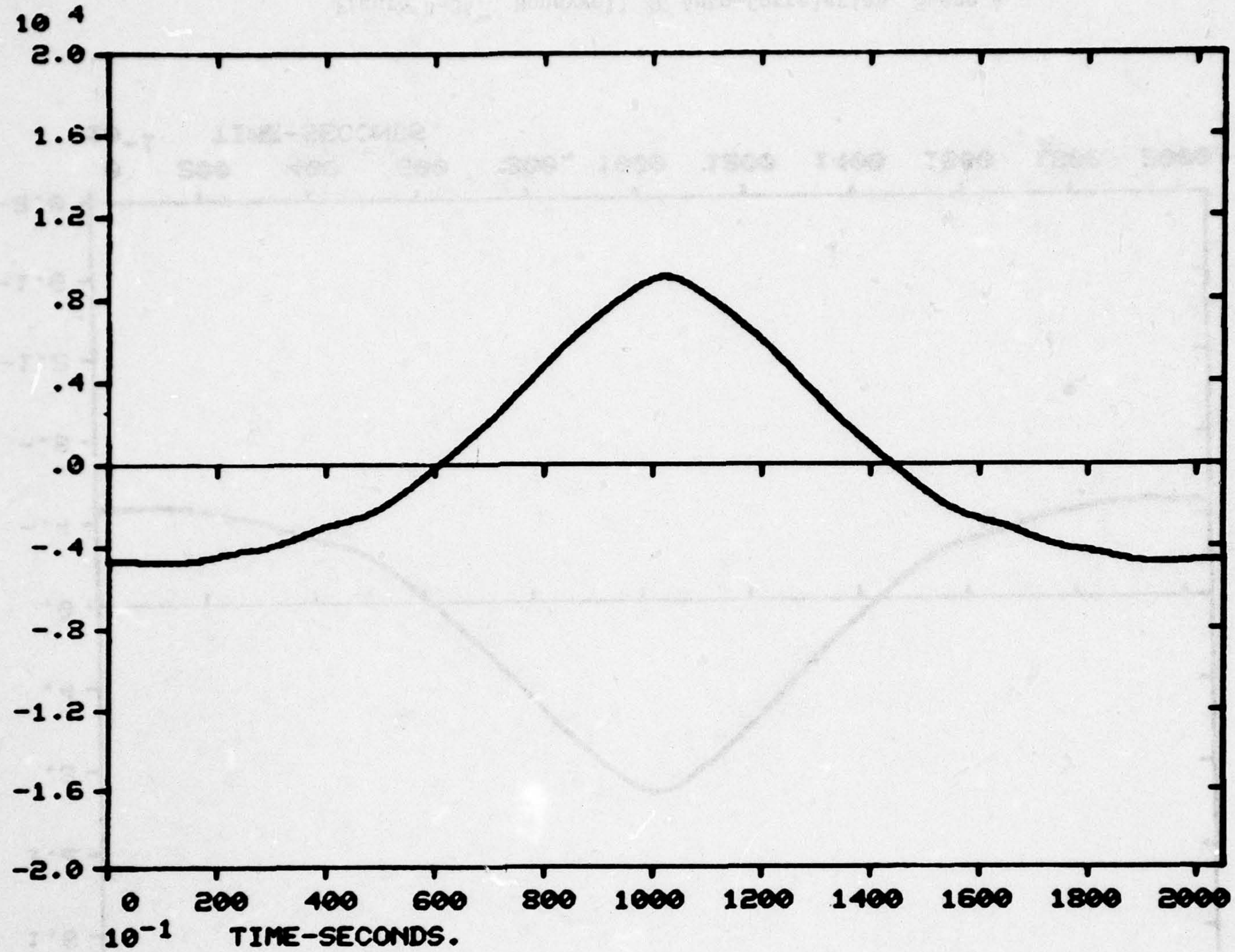


Figure B-35. Stewart-Warner 8K Auto Correlation, Scene 4

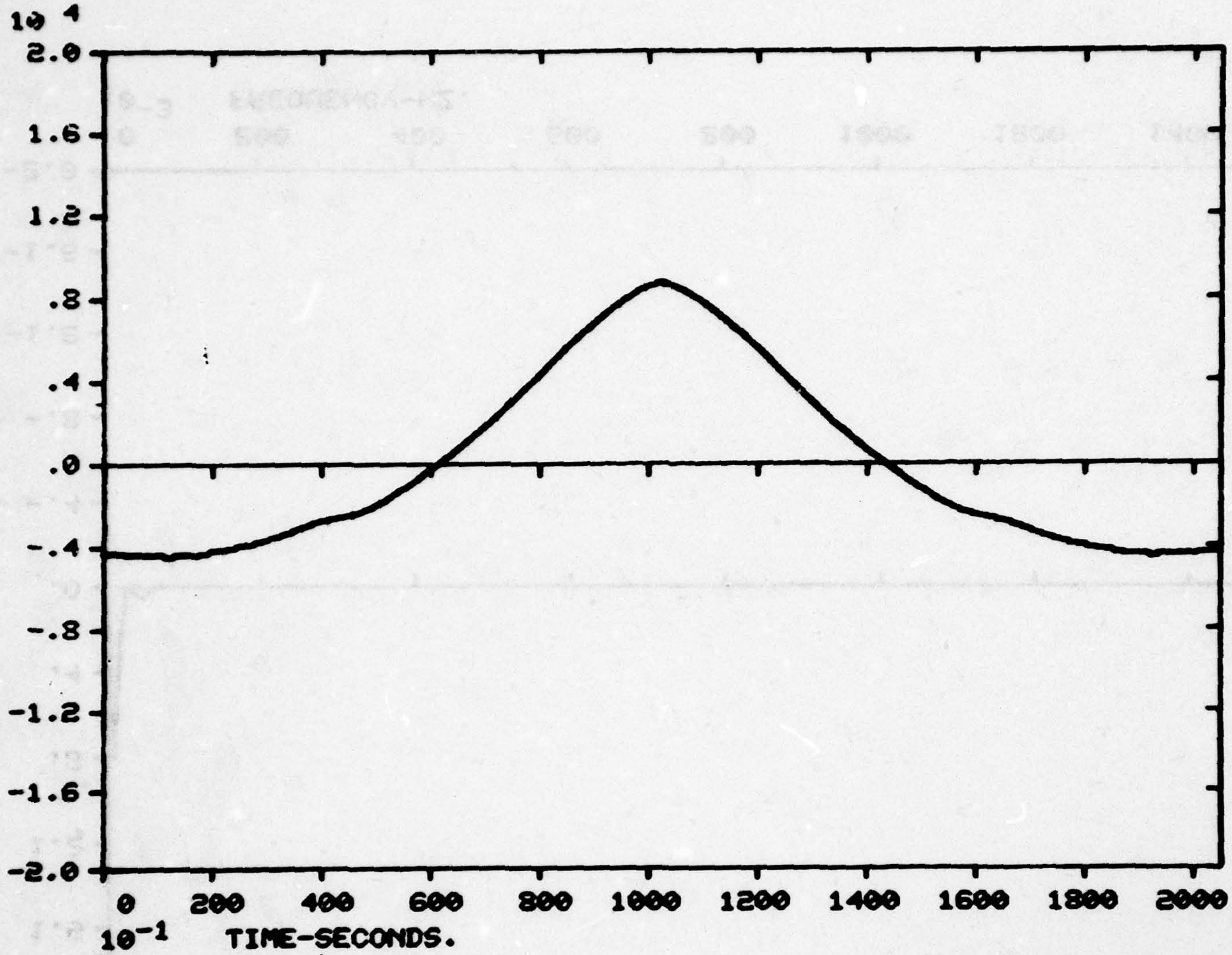


Figure B-36. Kollsman 8K Auto Correlation, Scene 4

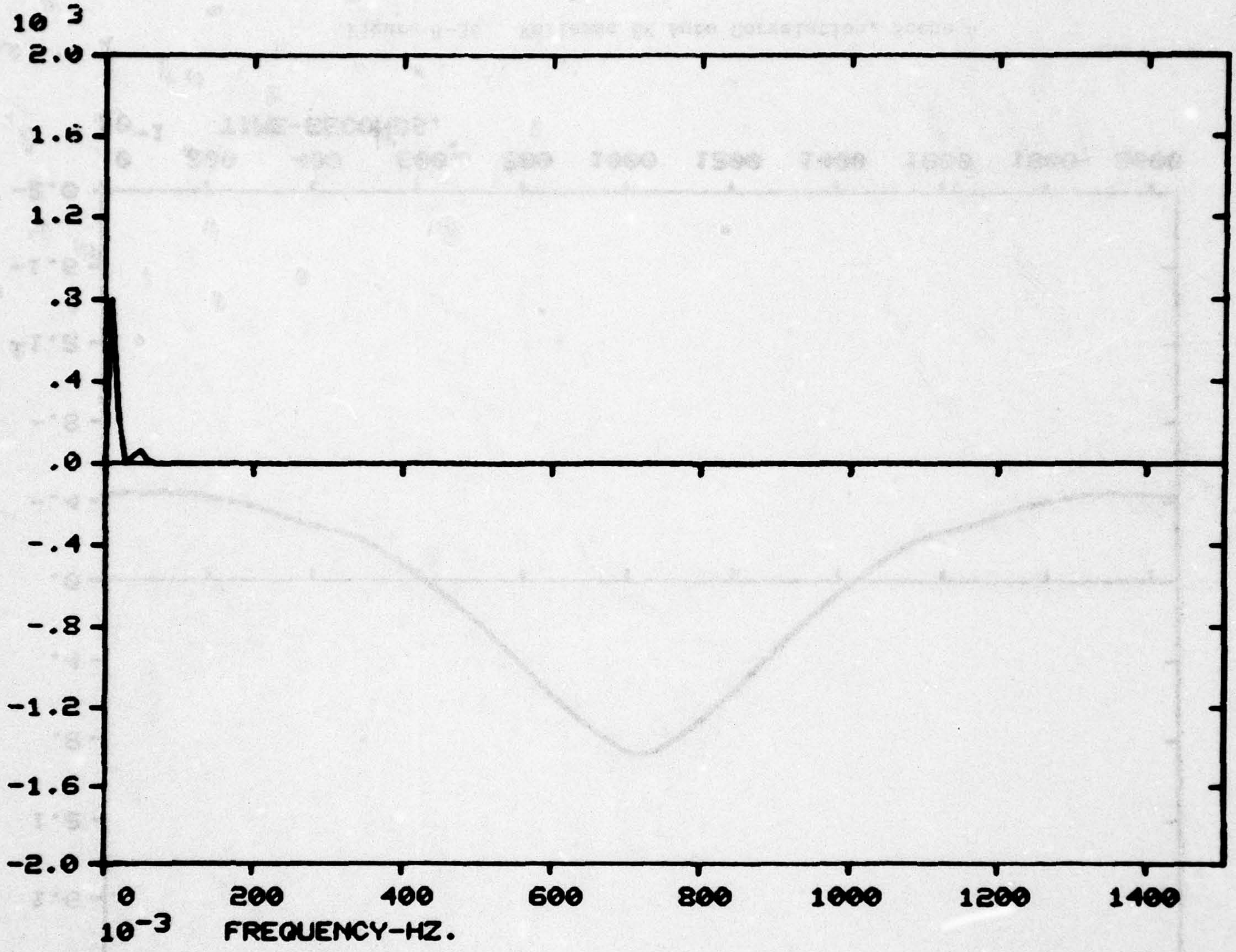


Figure B-37. Honeywell 63.5K PSD, Scene 4

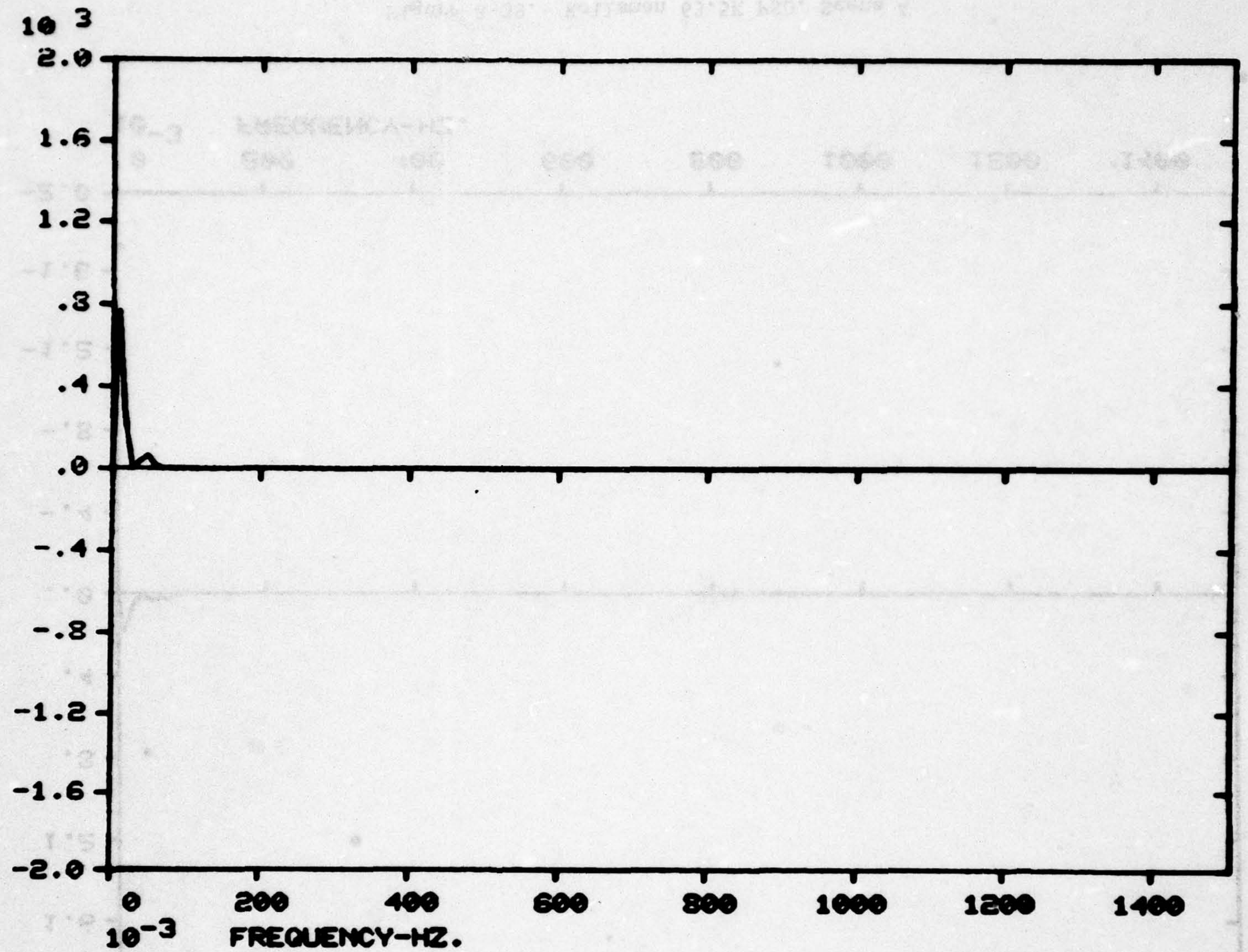


Figure B-38. Stewart-Warner 63.5K PSD, Scene 4

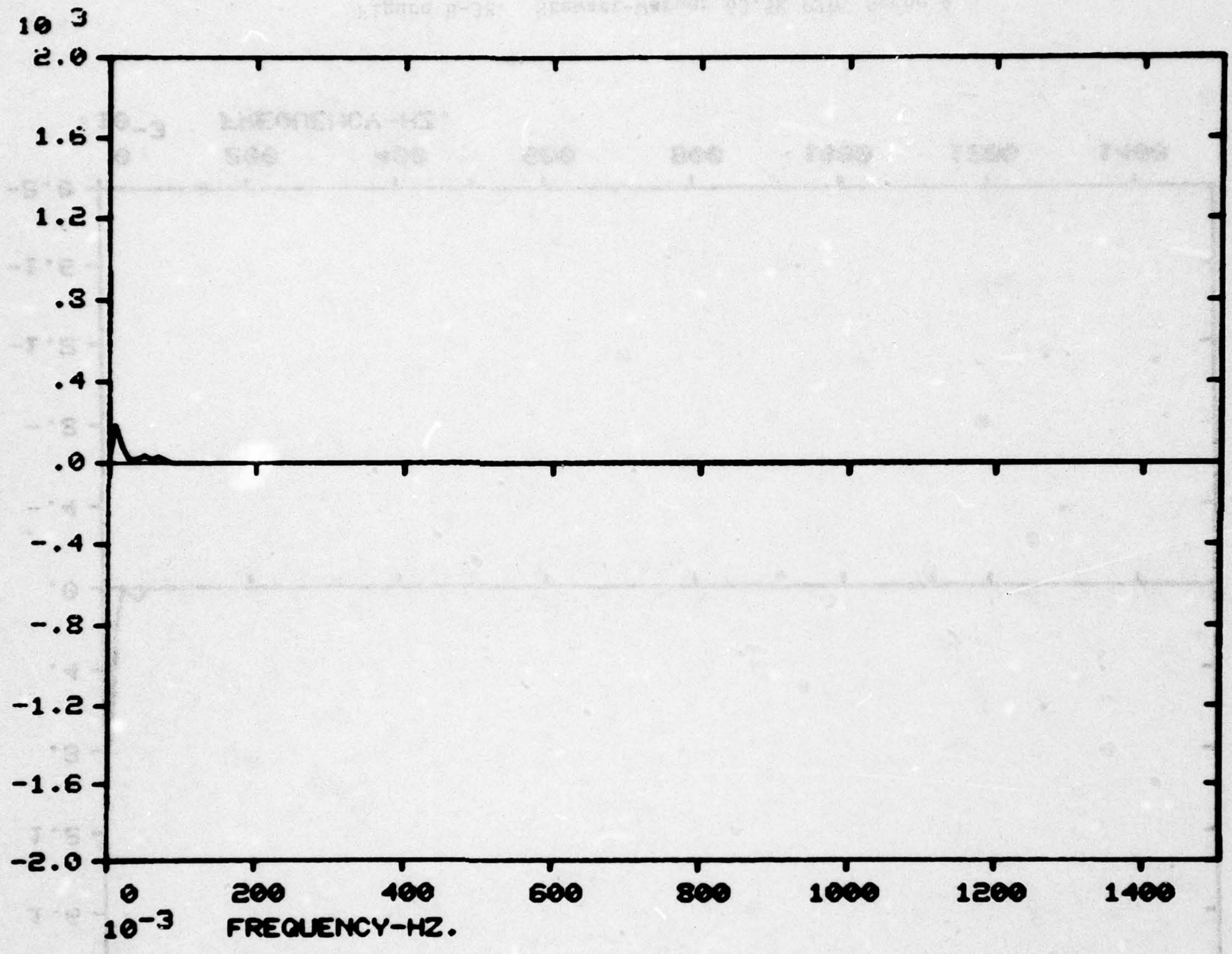


Figure B-39. Kollsman 63.5K PSD, Scene 4

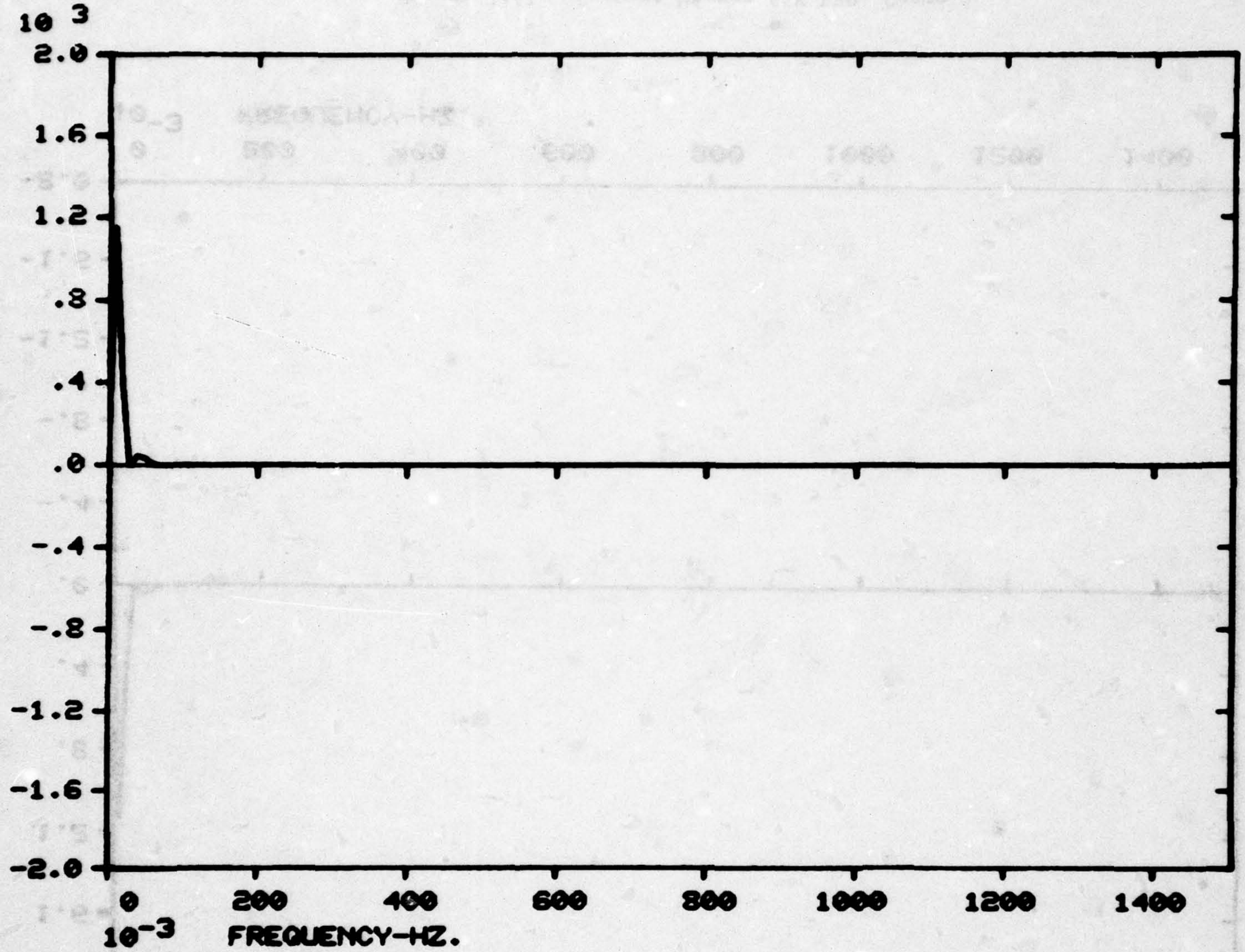


Figure B-40. Honeywell 45K PSD, Scene 4

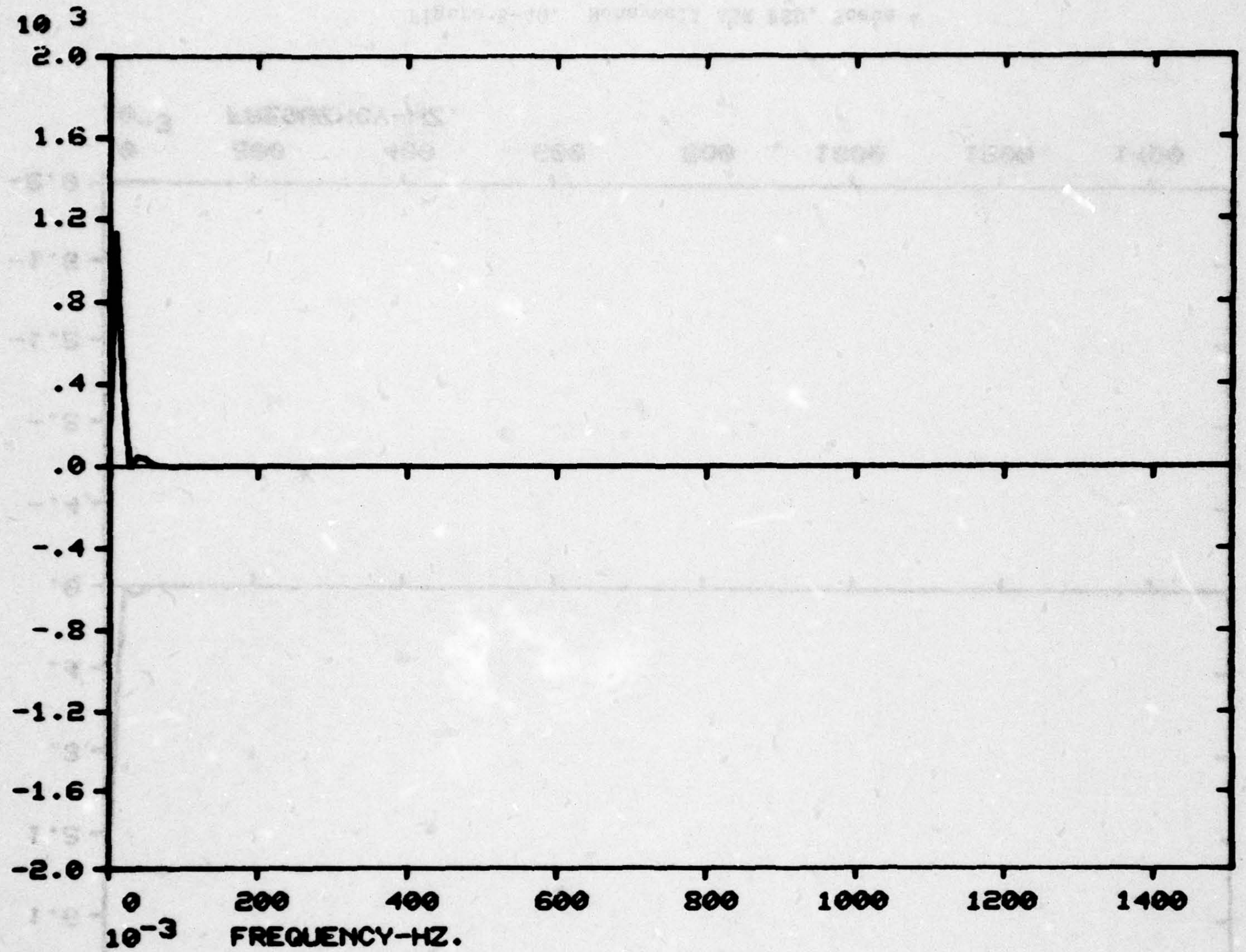


Figure B-41. Stewart-Warner 45K PSD, Scene 4

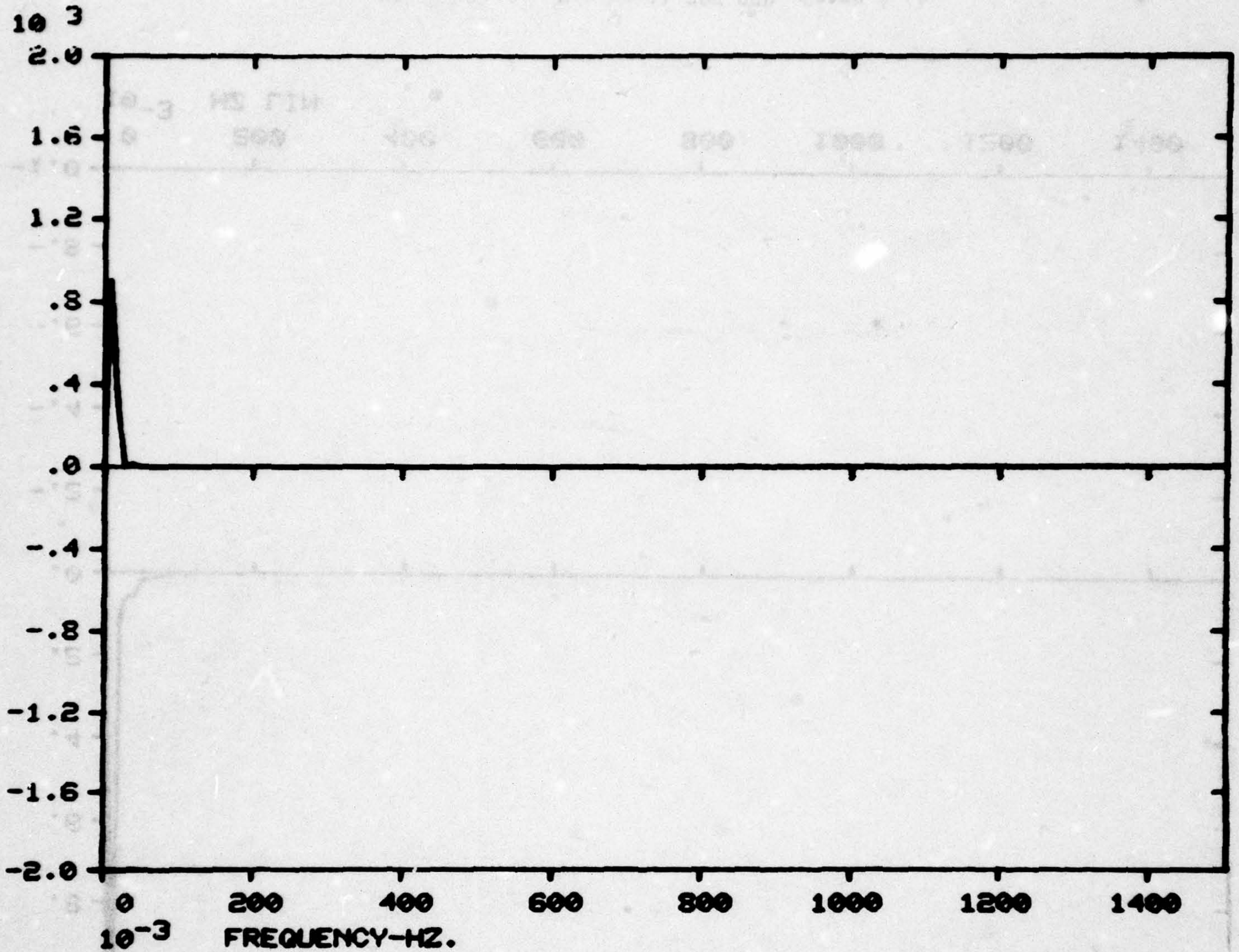


Figure B-42. Kollsman 45K PSD, Scene 4

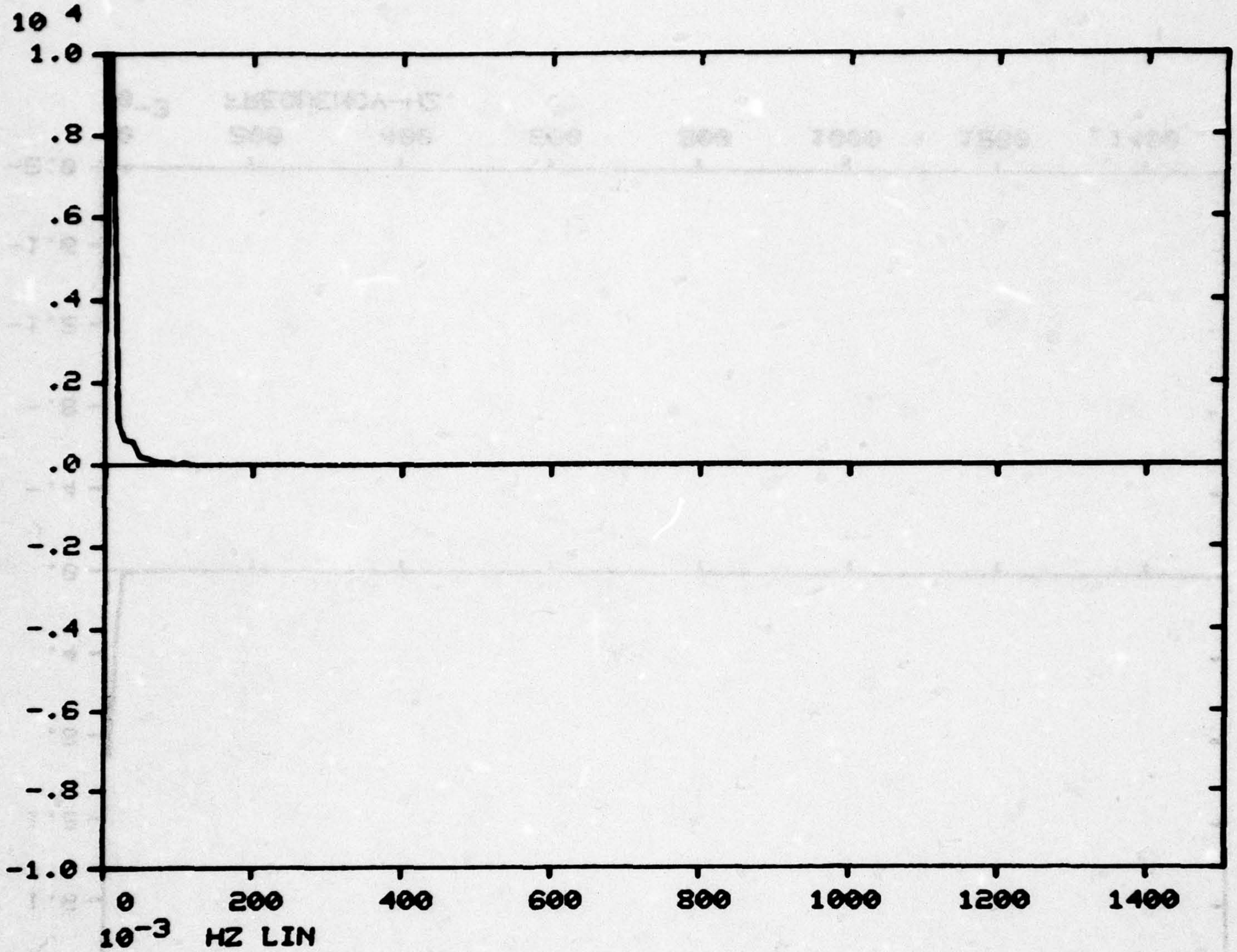


Figure B-43. Honeywell 20K PSD, Scene 4

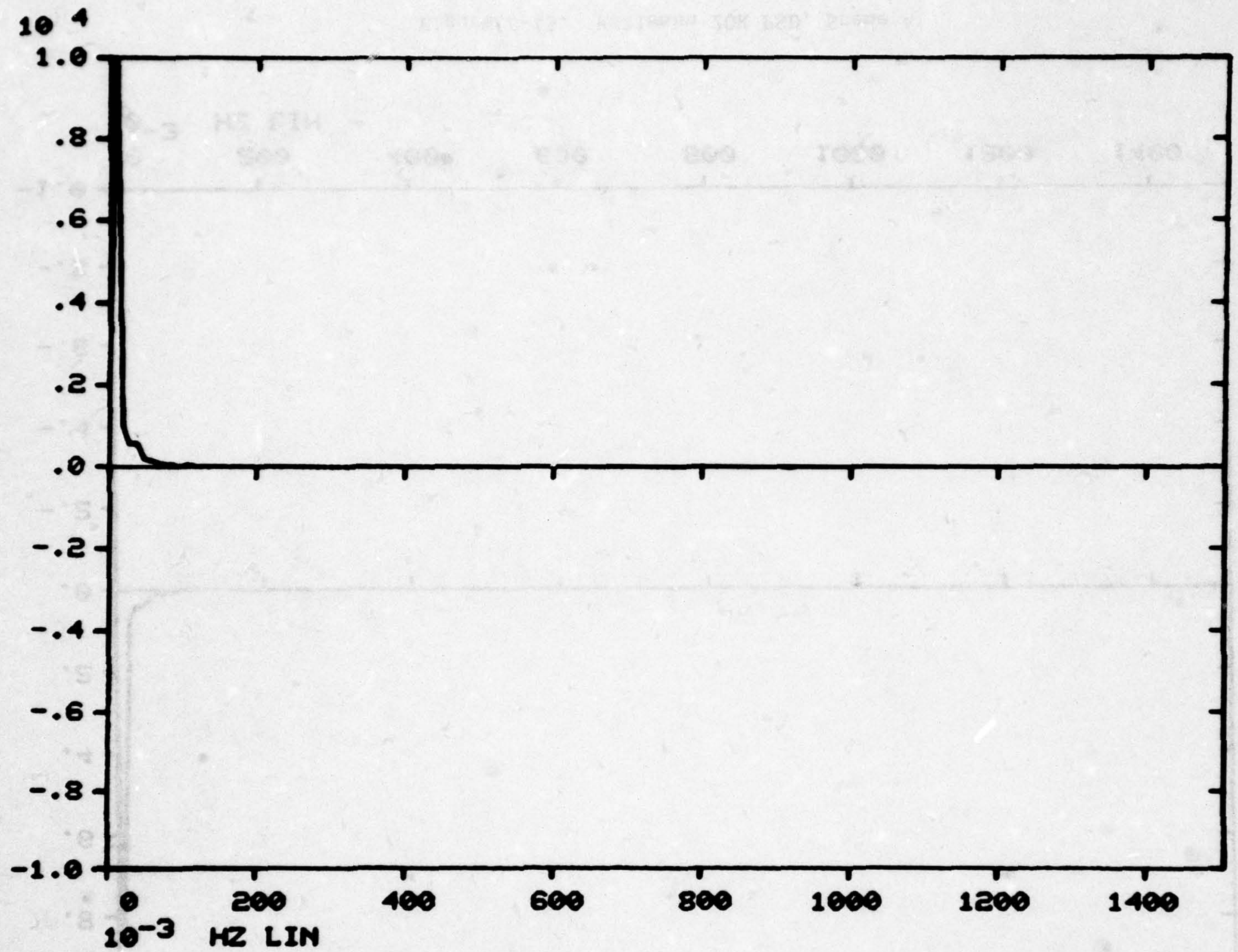


Figure B-44. Stewart-Warner 20K PSD, Scene 4

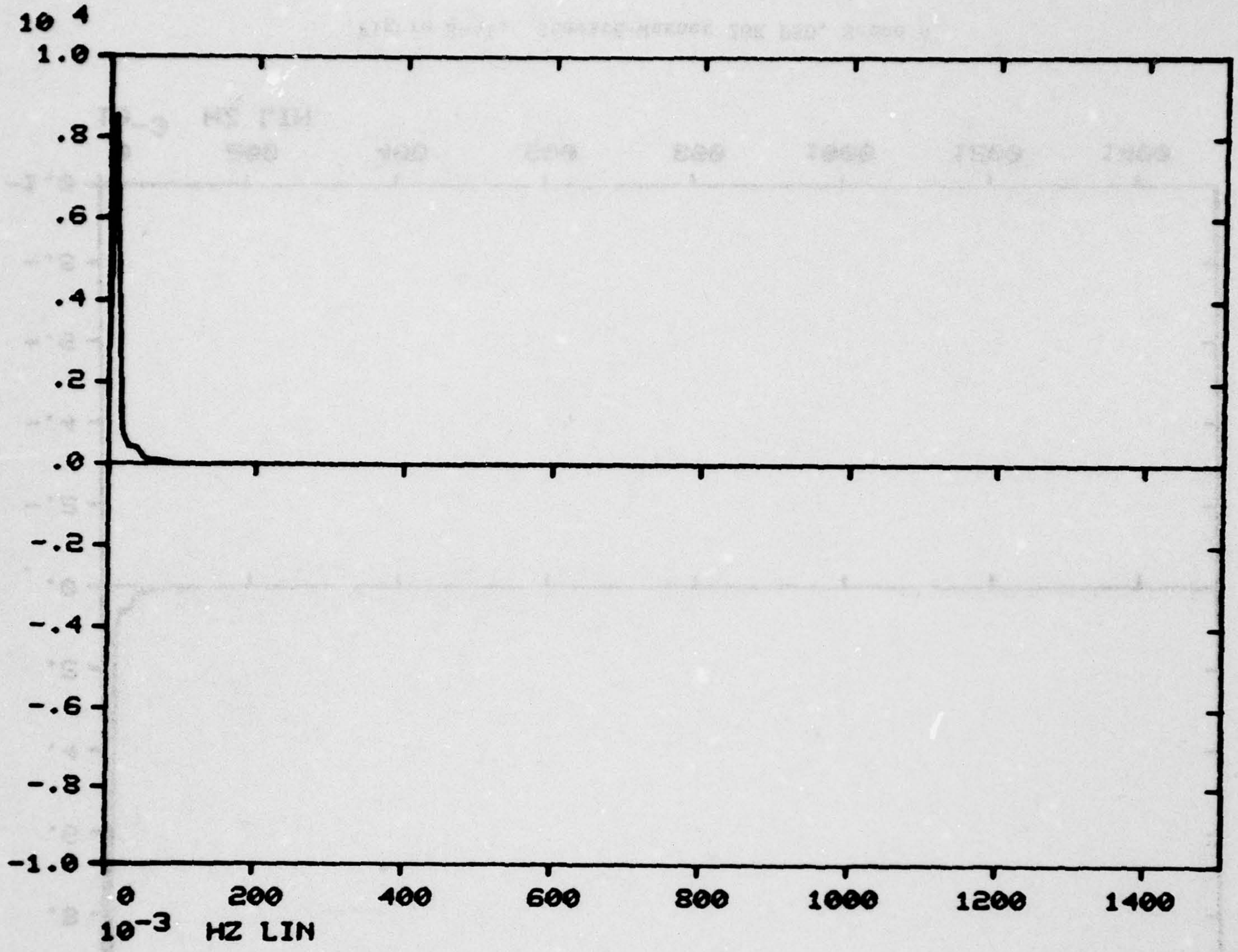


Figure B-45. Kollsman 20K PSD, Scene 4

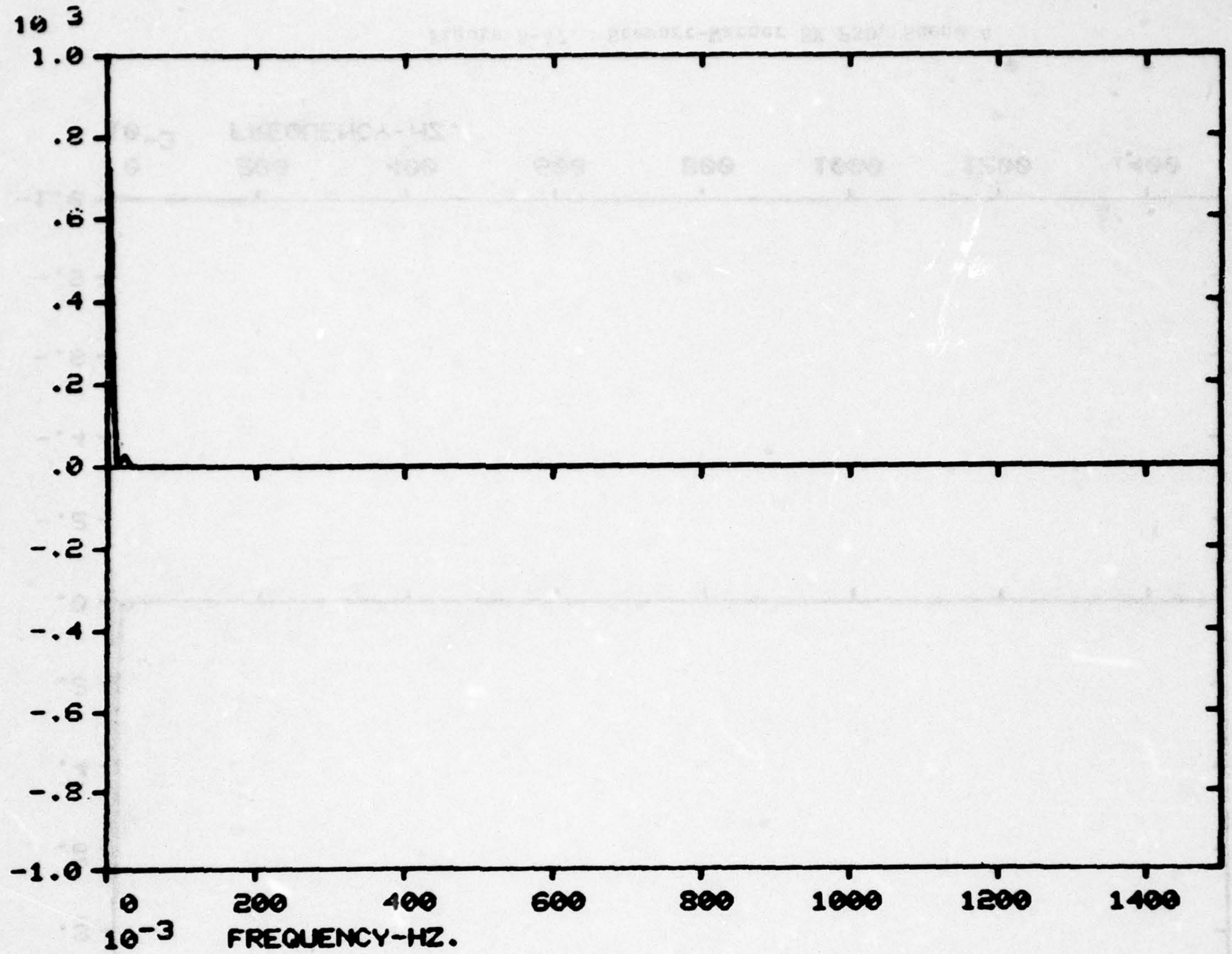


Figure B-46. Honeywell 8K PSD, Scene 4

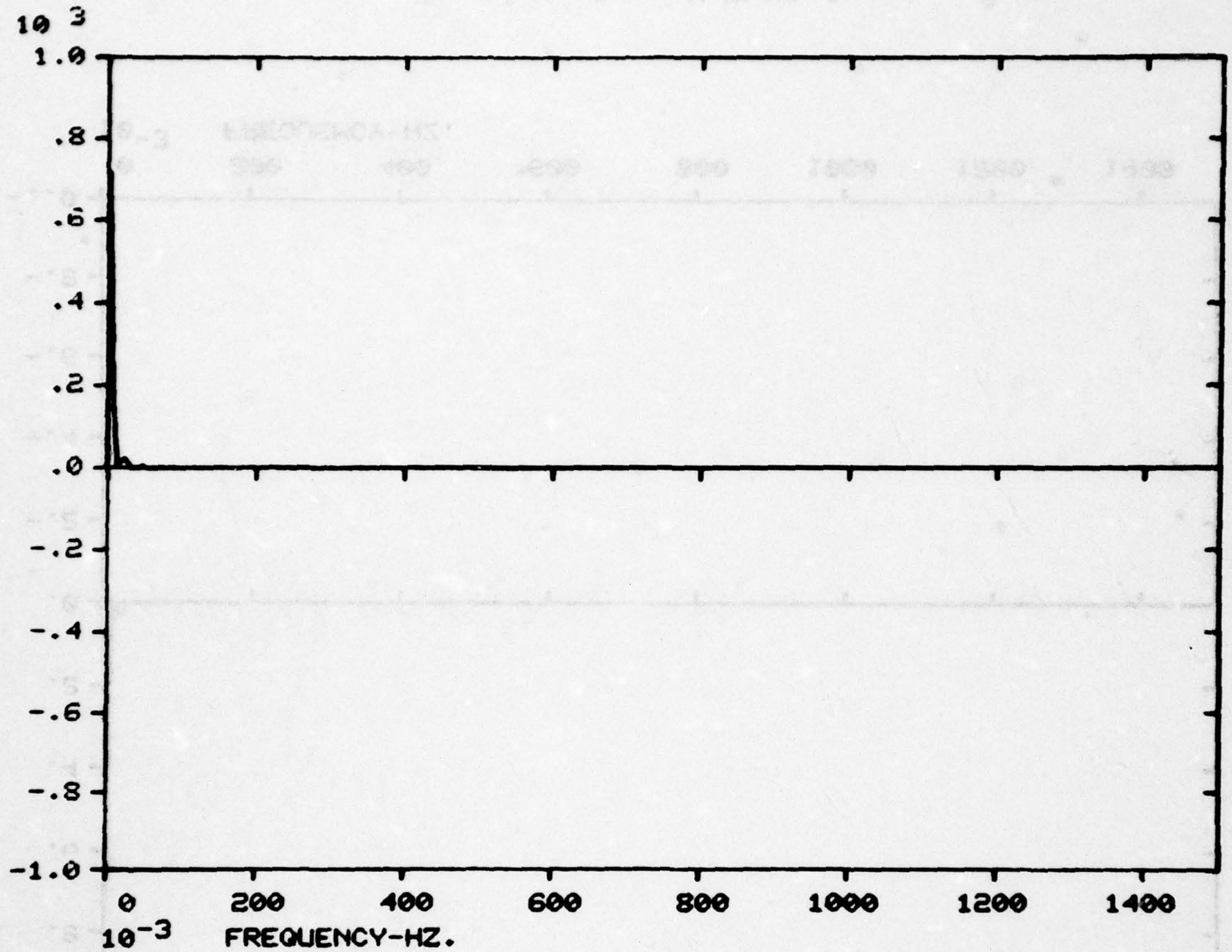


Figure B-47. Stewart-Warner 8K PSD, Scene 4

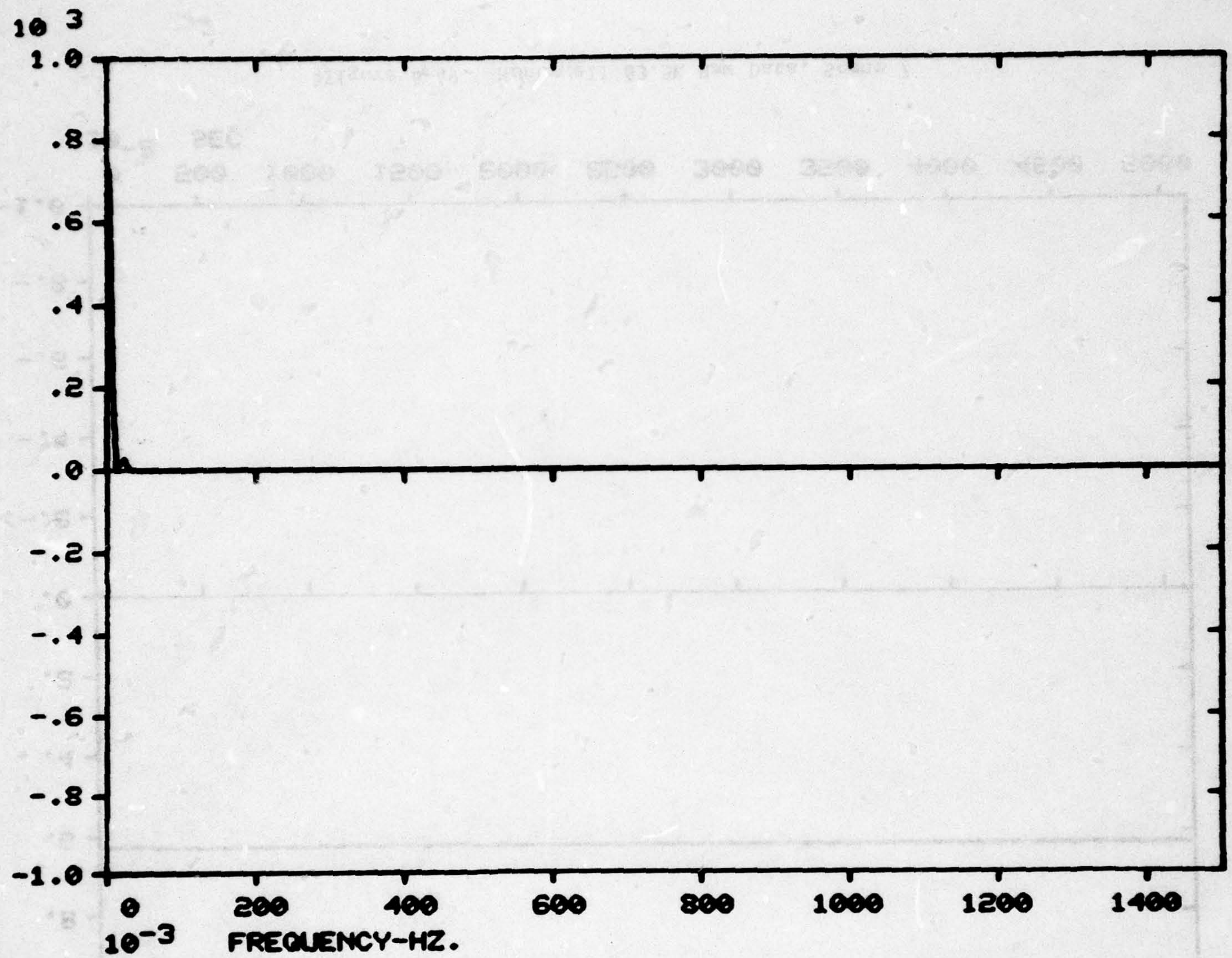


Figure B-48. Kollsman 8K PSD, Scene 4

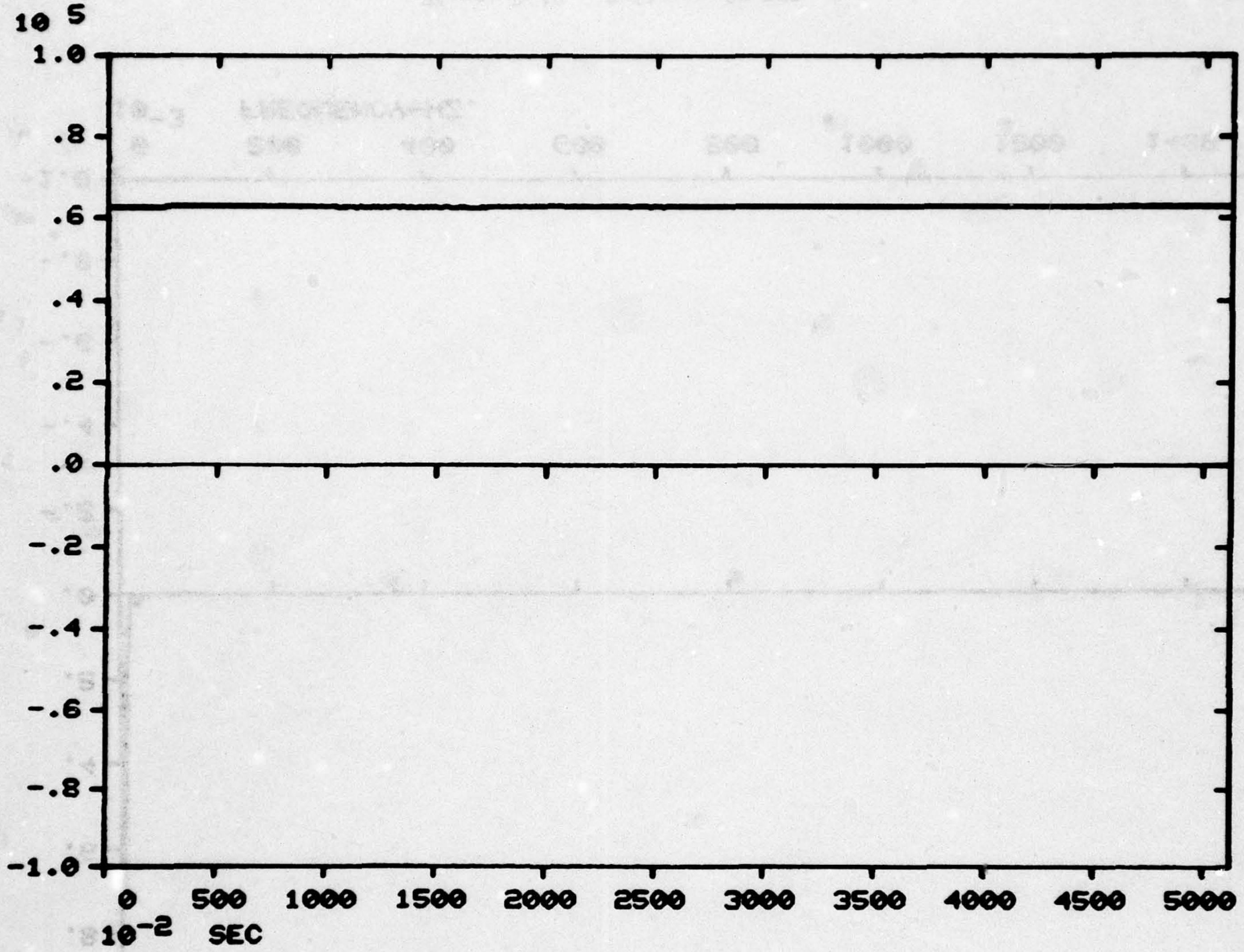


Figure B-49. Honeywell 63.5K Raw Data, Scene 7

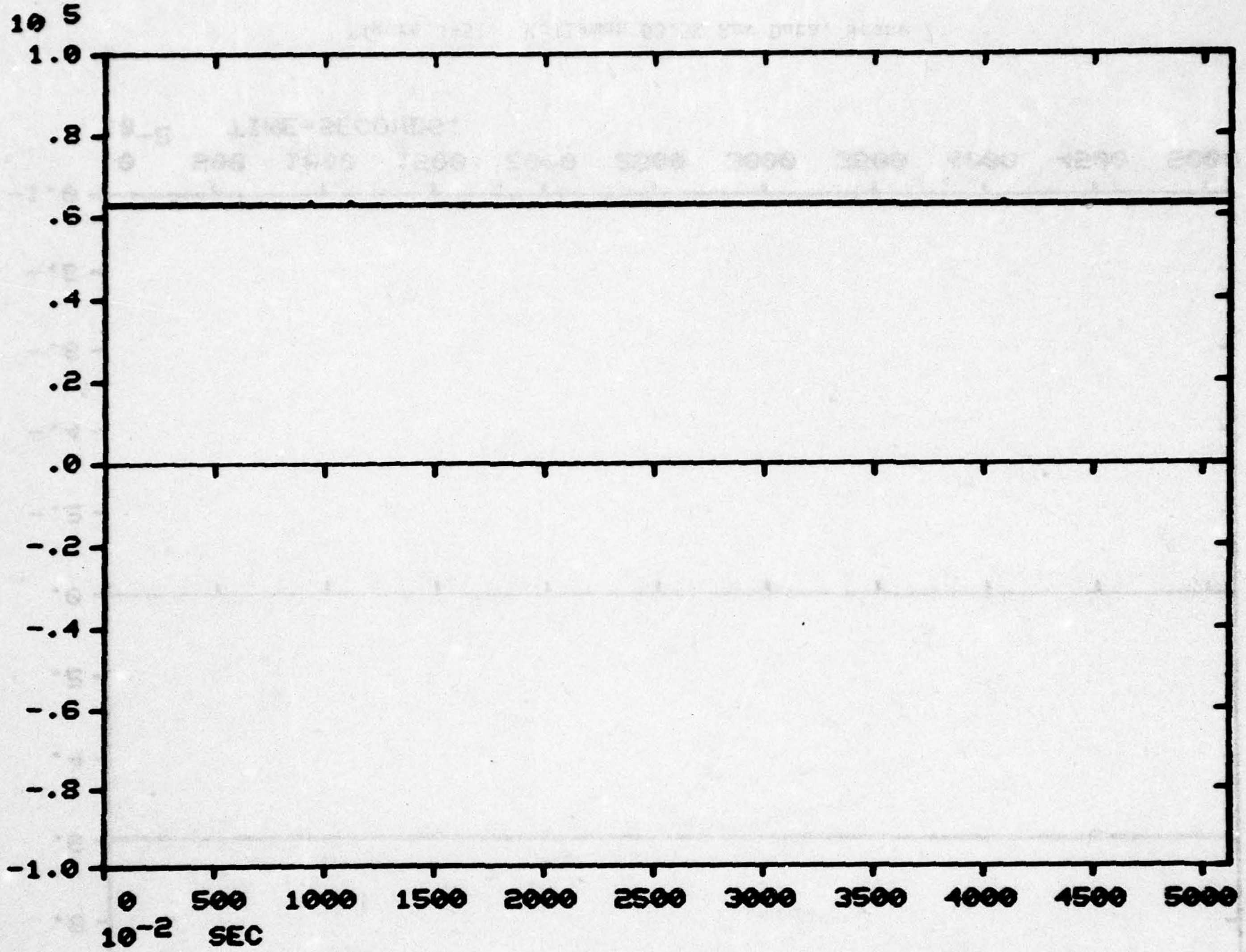


Figure B-50. Stewart-Warner 63.5K Raw Data, Scene 7

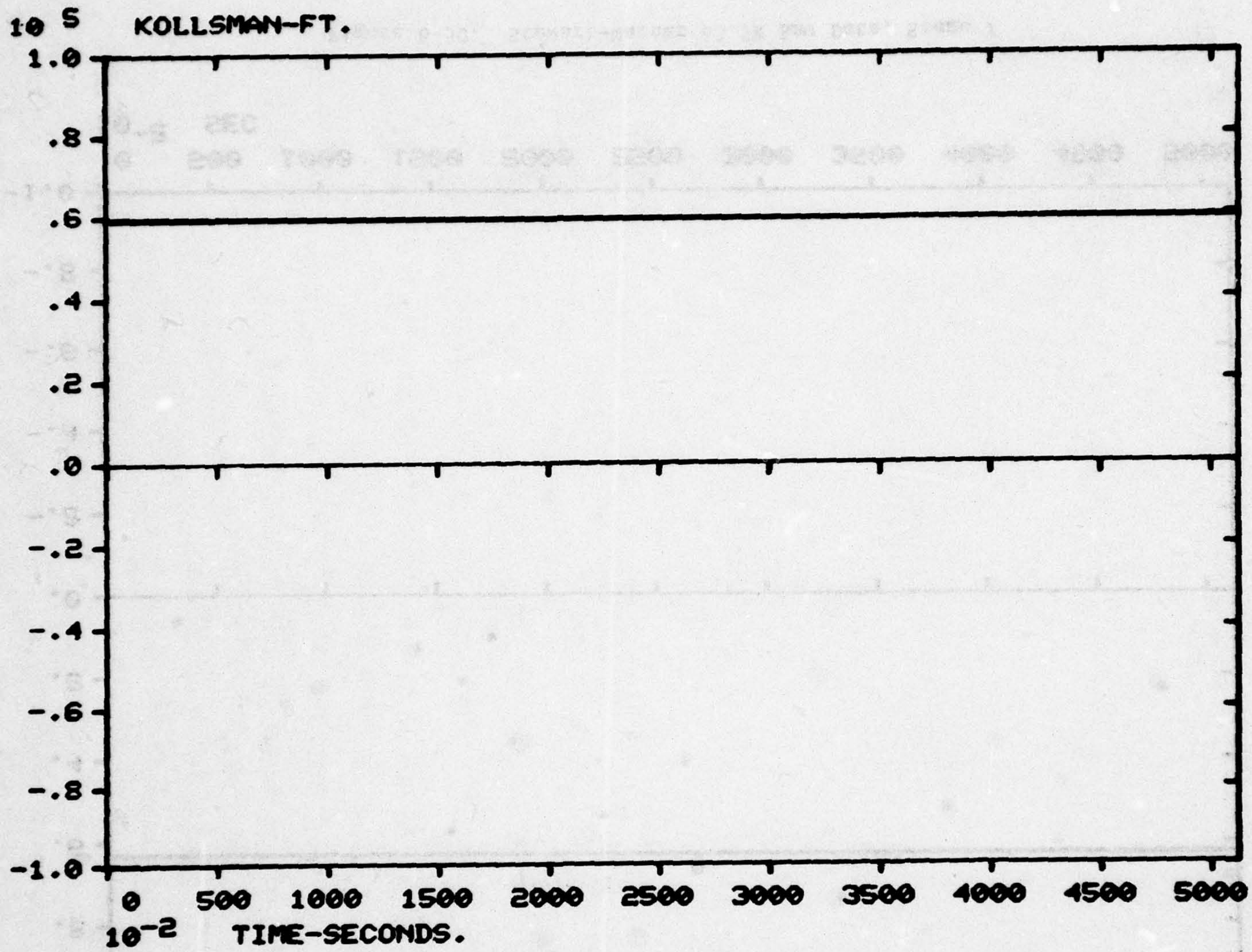


Figure B-51. Kollsman 63.5K Raw Data, Scene 7

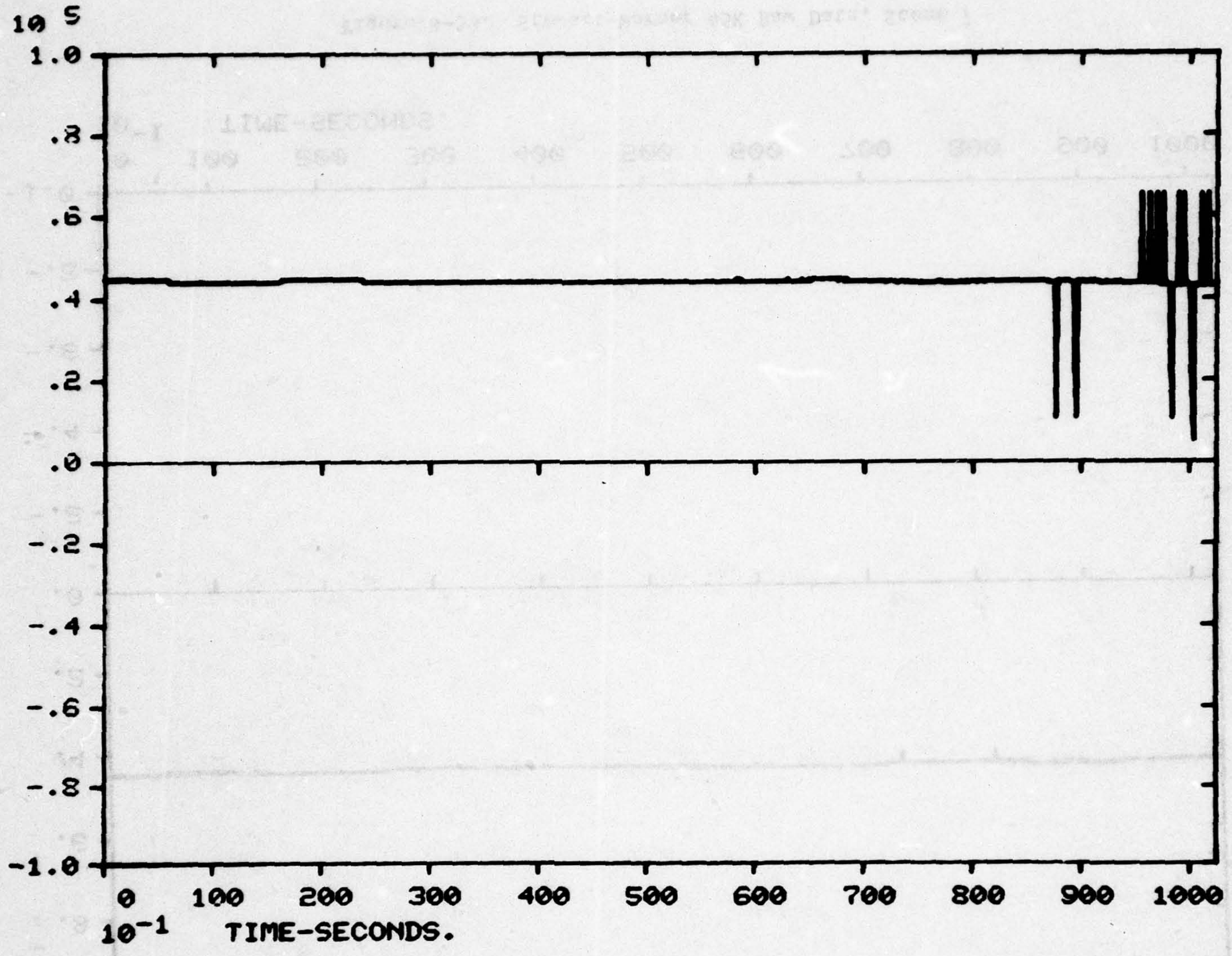


Figure B-52. Honeywell 45K Raw Data, Scene 7

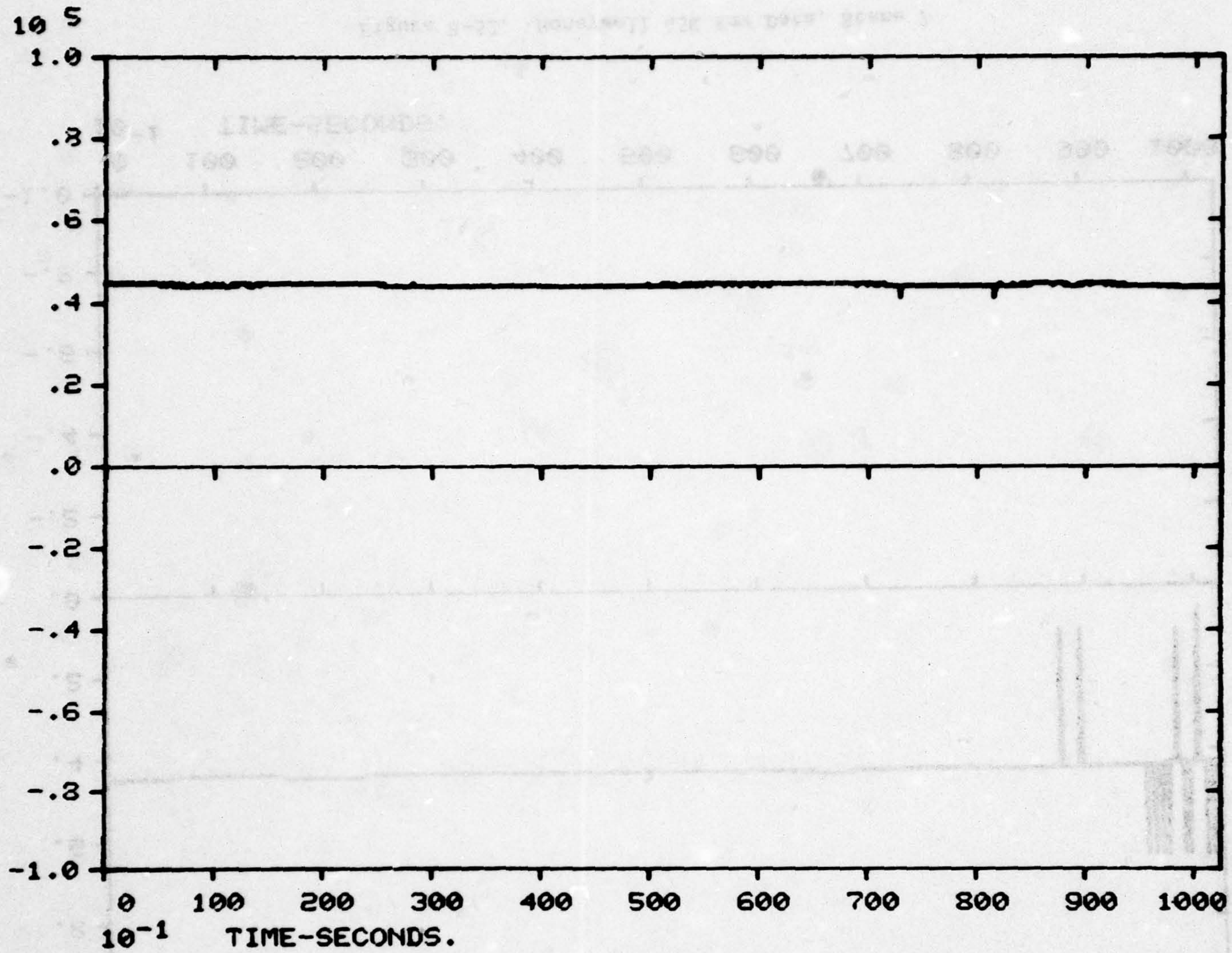


Figure B-53. Stewart-Warner 45K Raw Data, Scene 7

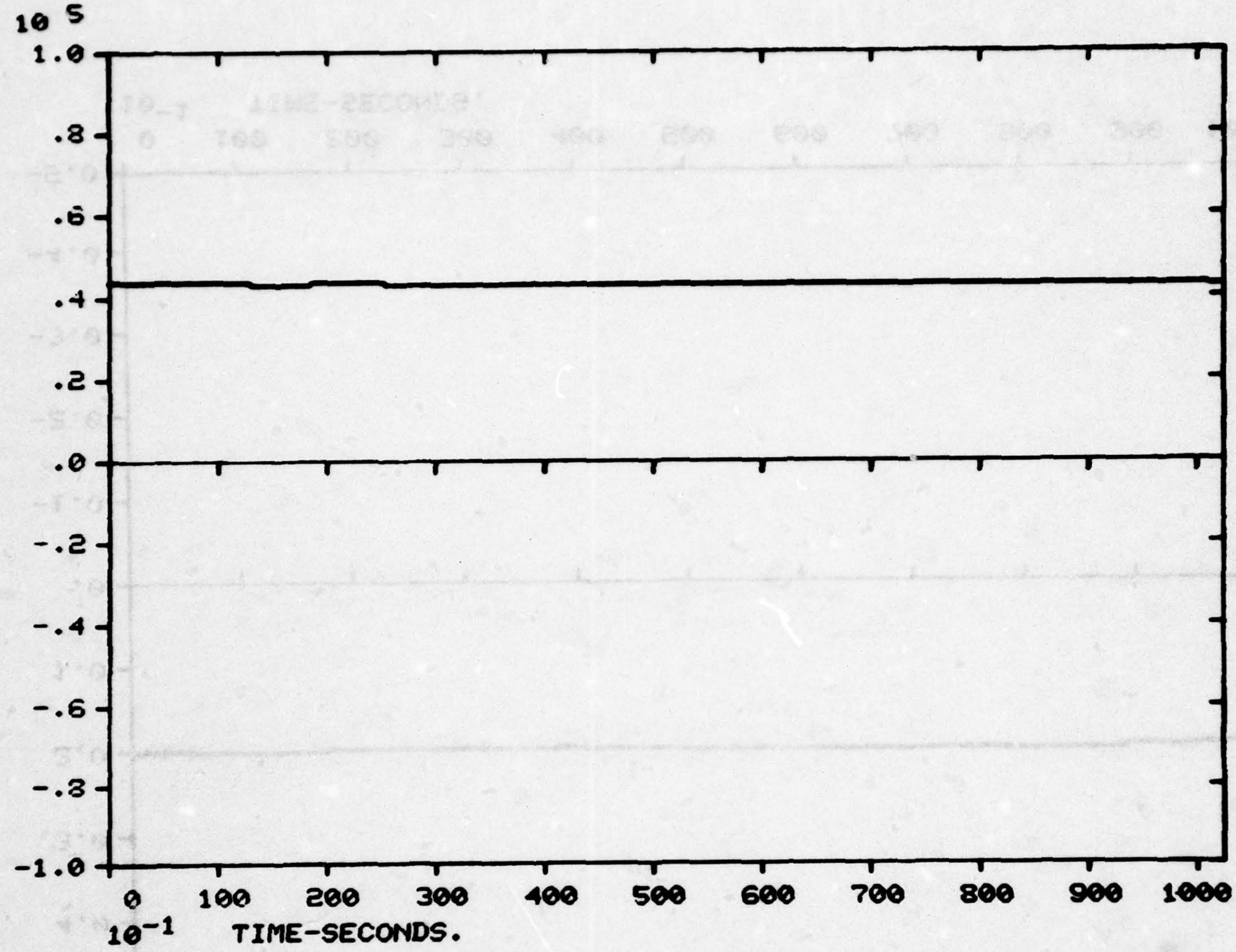


Figure B-54. Kollsman 45K Raw Data, Scene 7

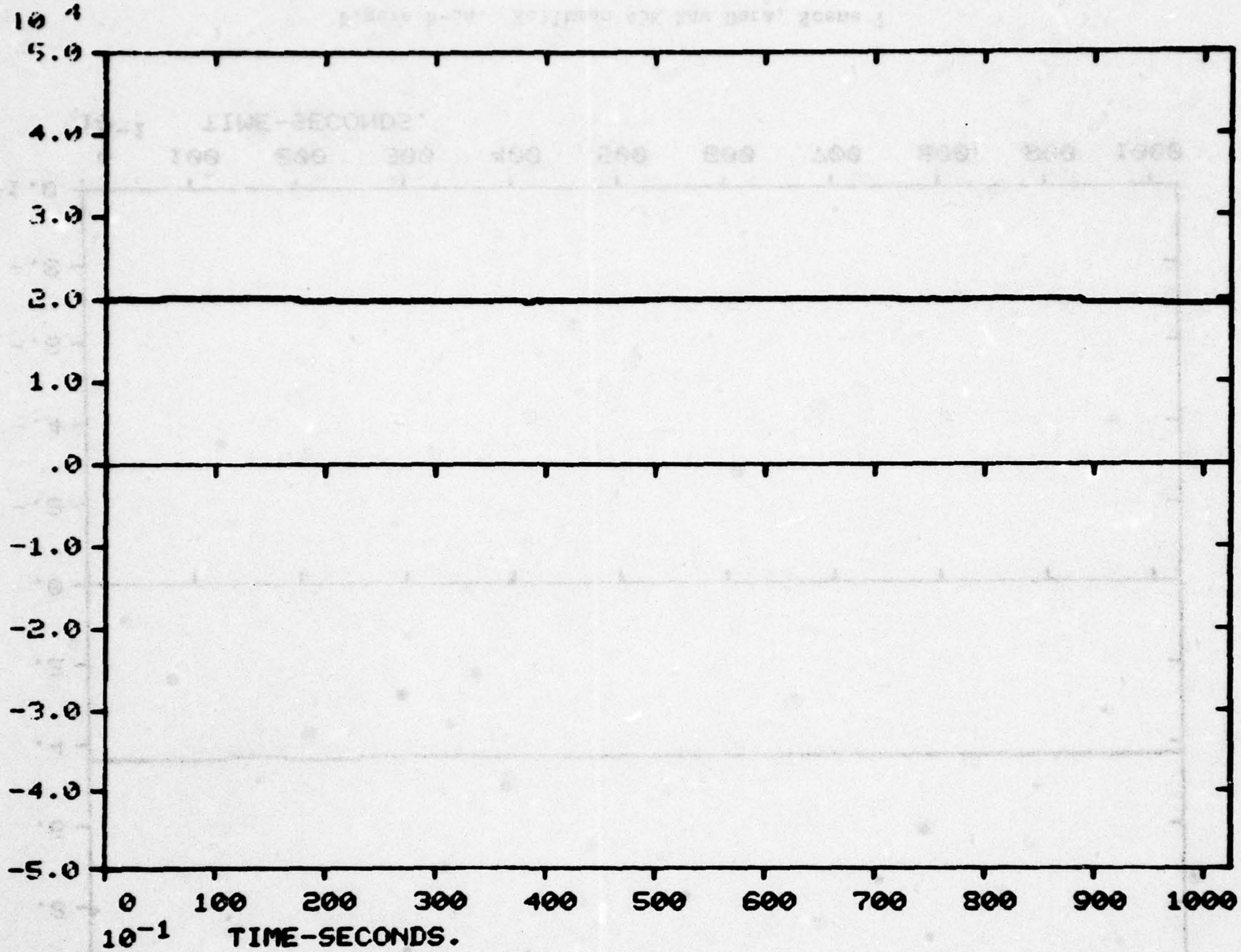


Figure B-55. Honeywell 20K Raw Data, Scene 7

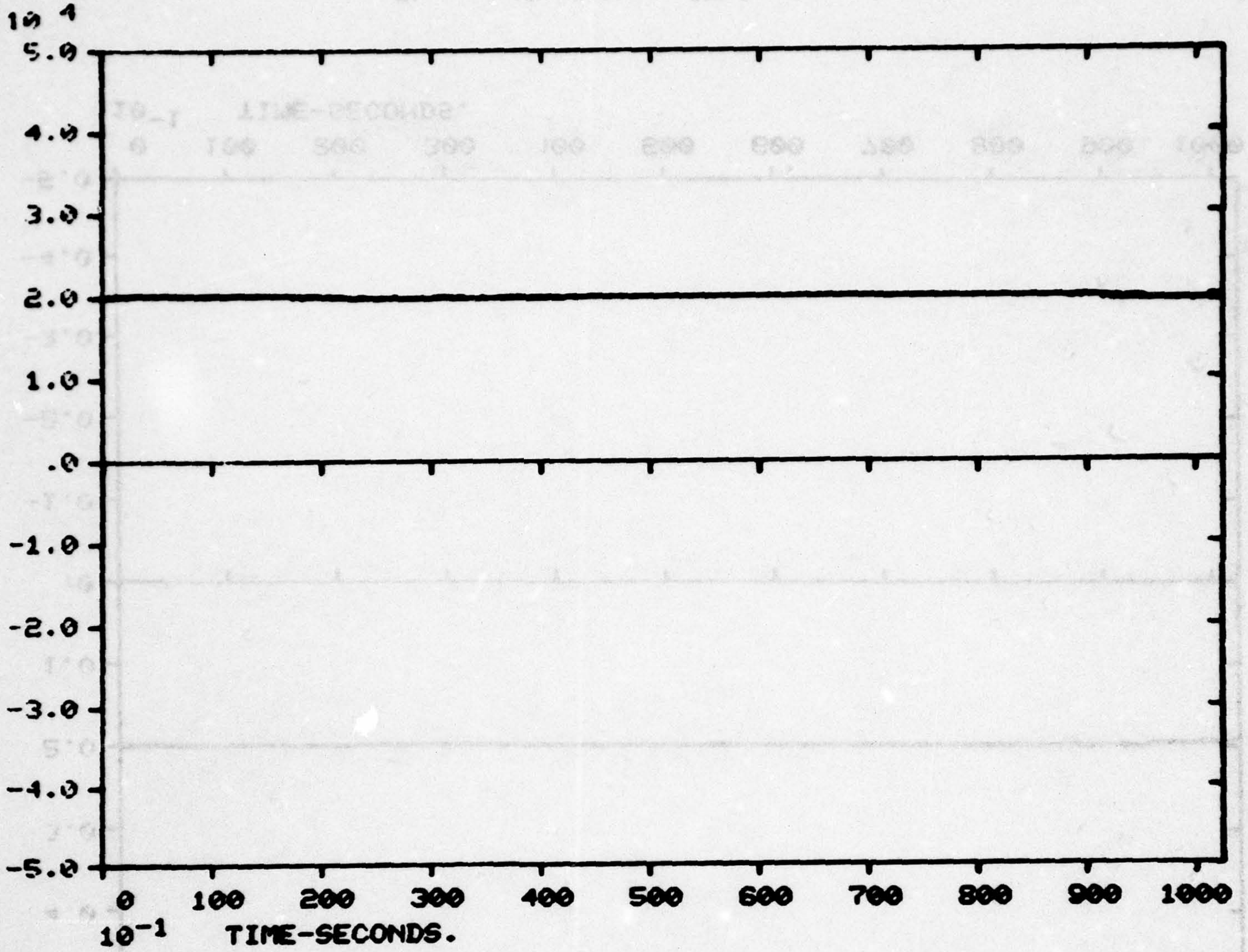


Figure B-56. Stewart-Warner 20K Raw Data, Scene 7

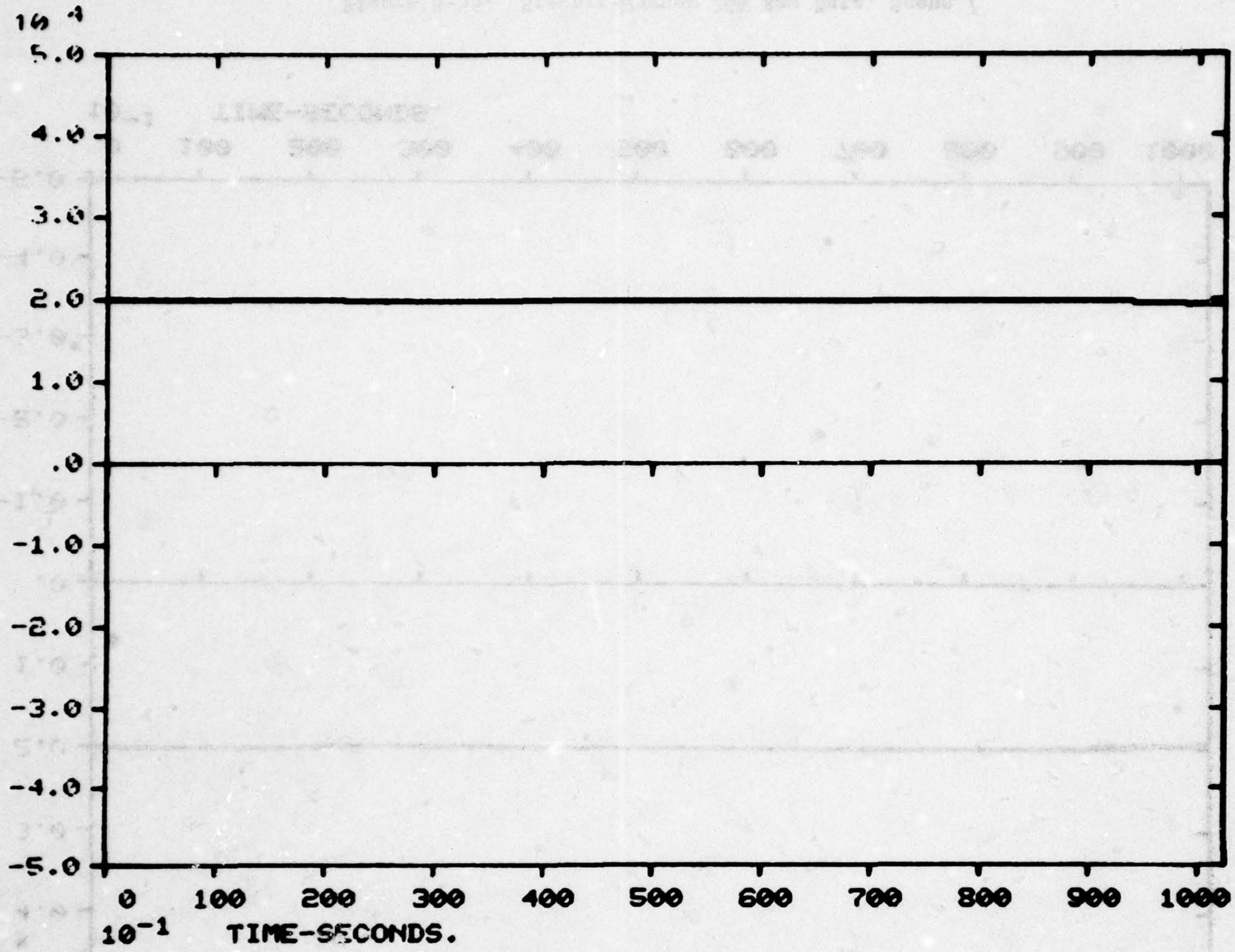


Figure B-57. Kollsman 20K Raw Data, Scene 7

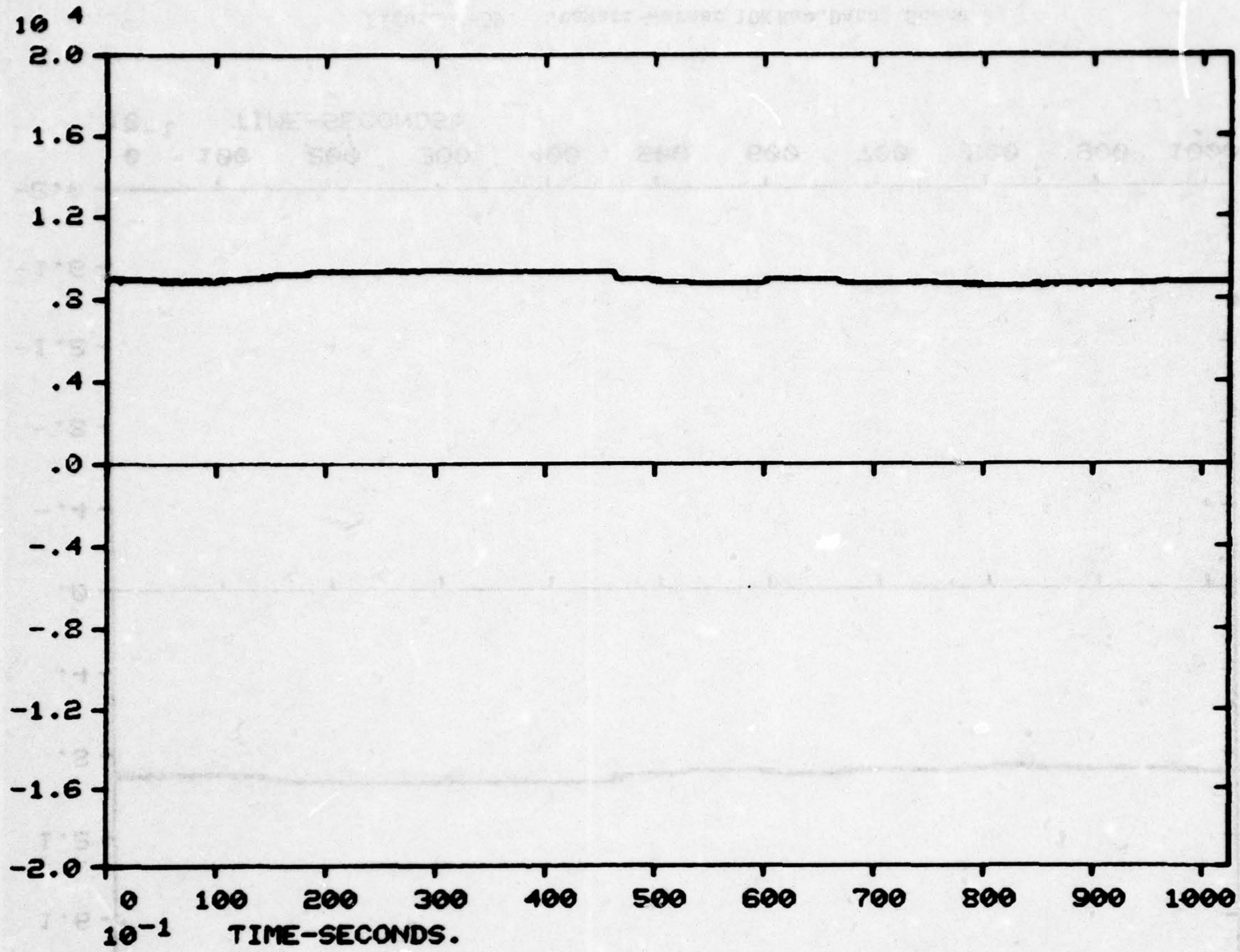


Figure B-58. Honeywell 10K Raw Data, Scene 7

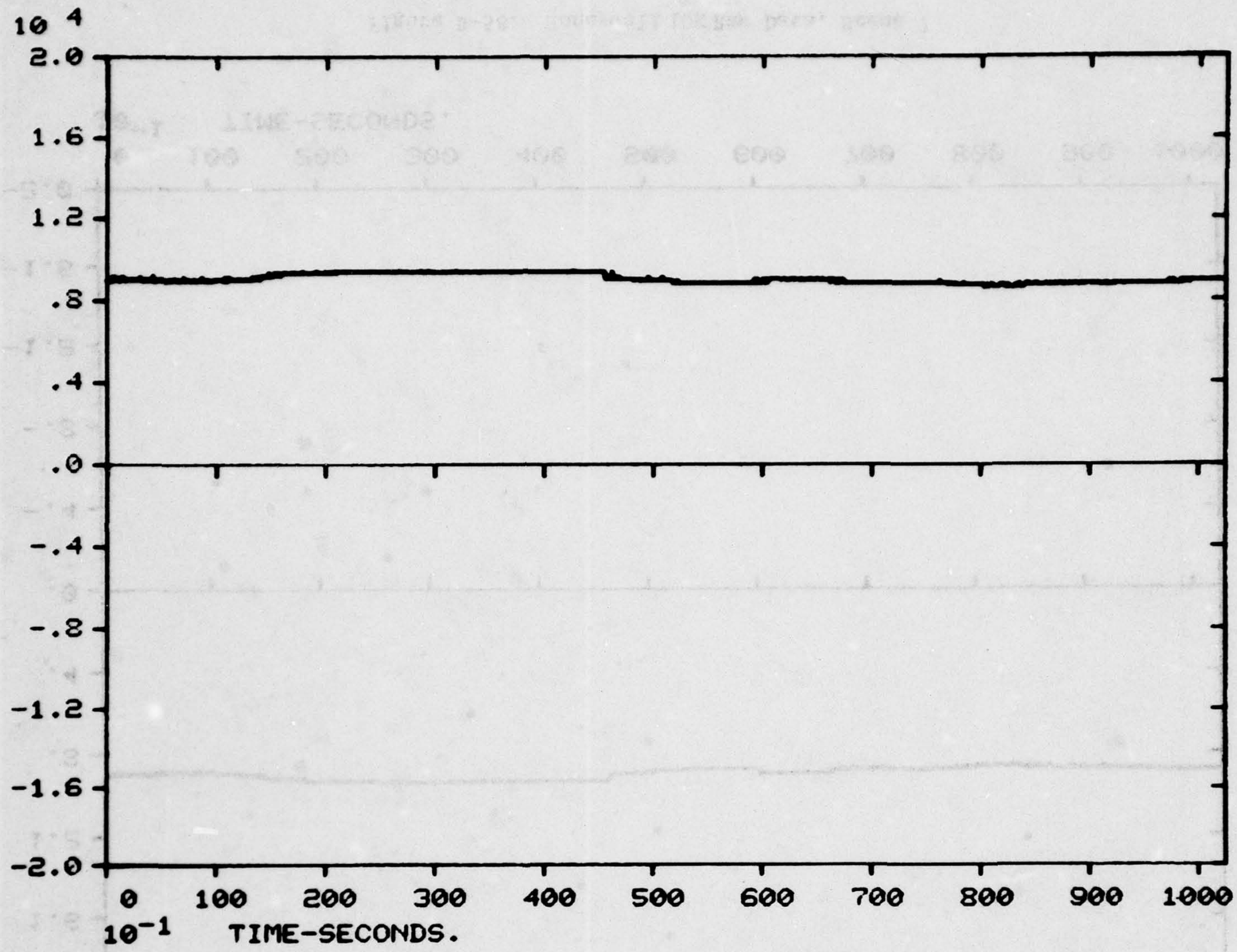


Figure B-59. Stewart-Warner 10K Raw Data, Scene 7

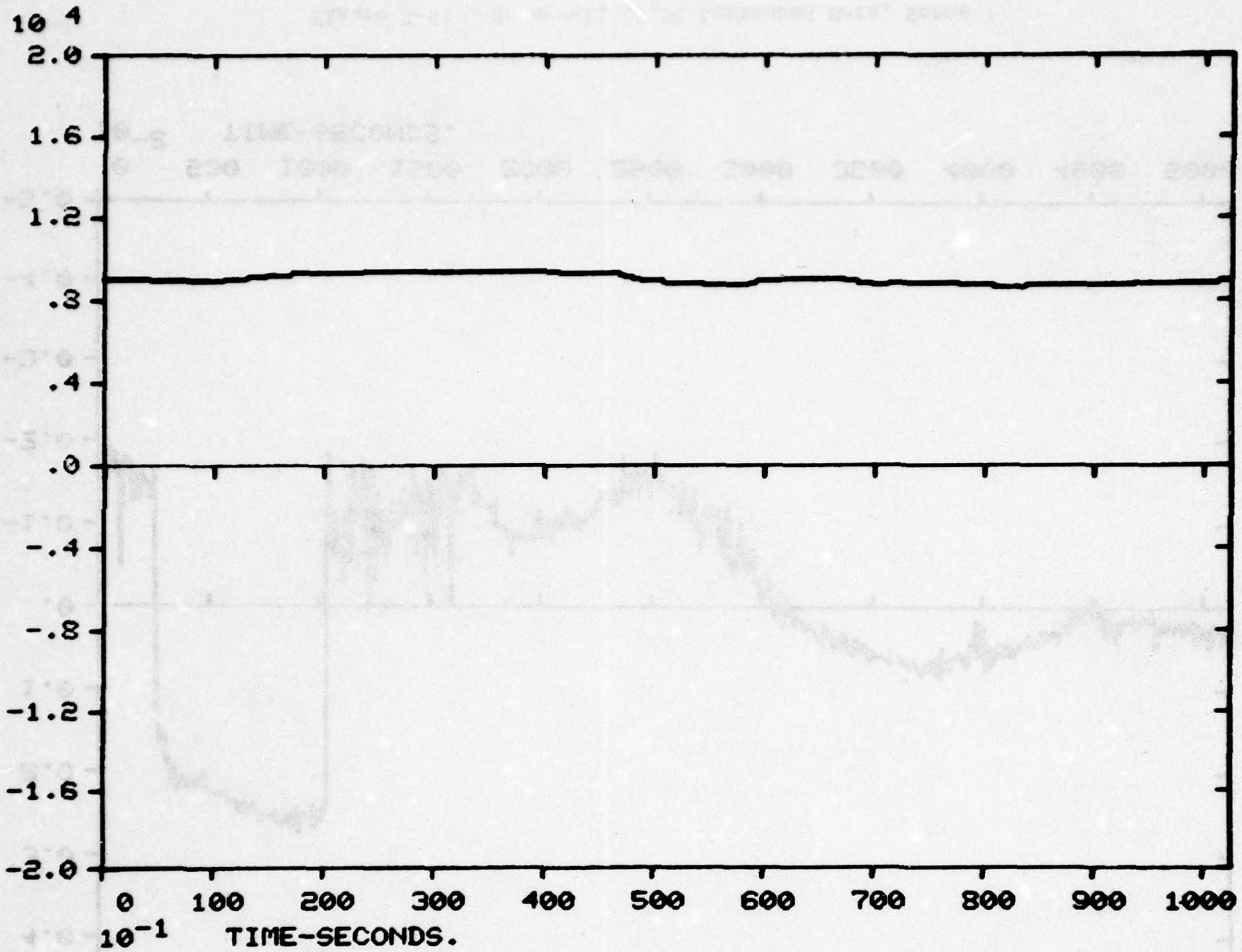


Figure B-60. Kollsman 10K Raw Data, Scene 7

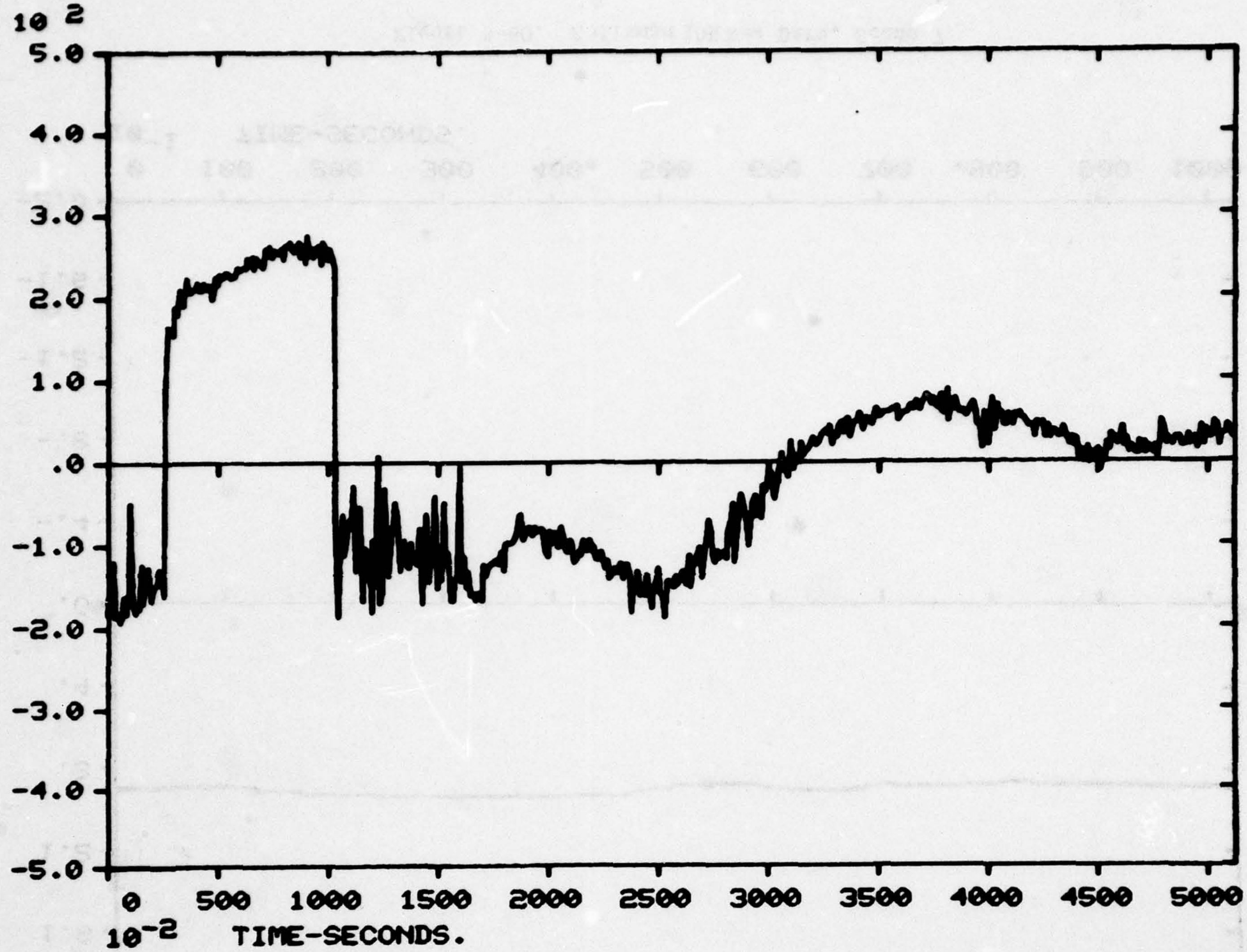


Figure B-61. Honeywell 63.5K Detrended Data, Scene 7

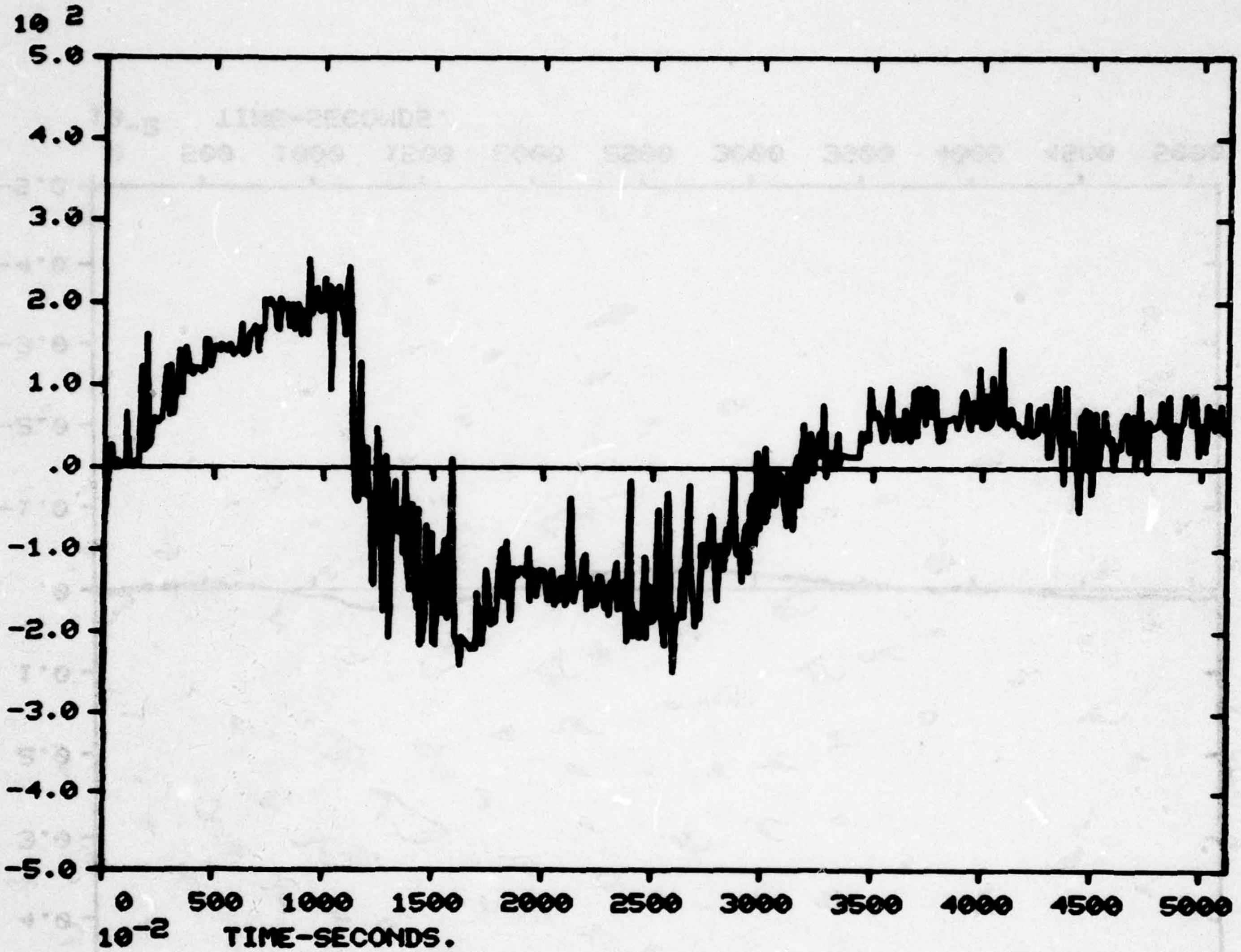


Figure B-62. Stewart-Warner 63.5K Detrended Data, Scene 7

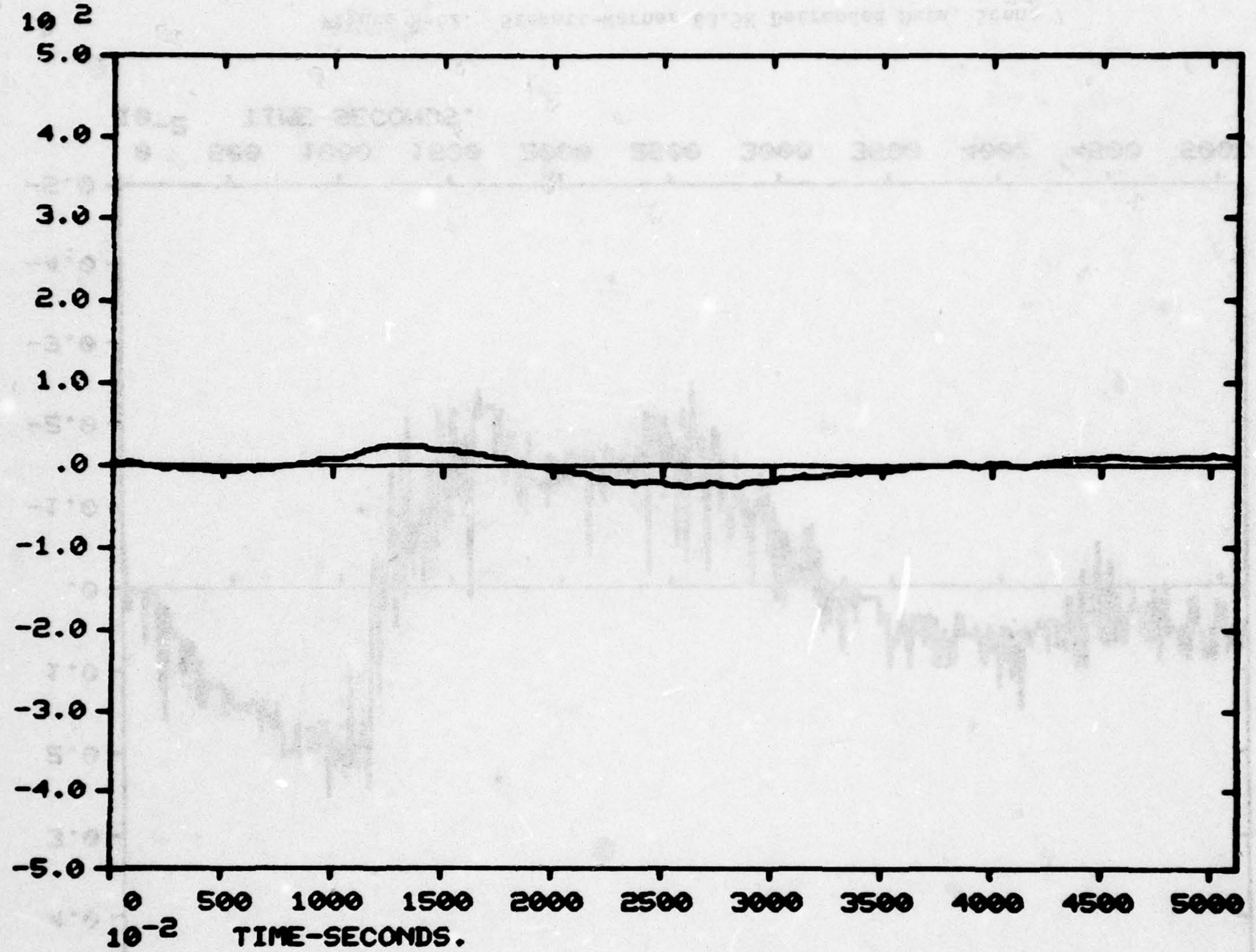


Figure B-63. Kollsman 63.5K Detrended Data, Scene 7

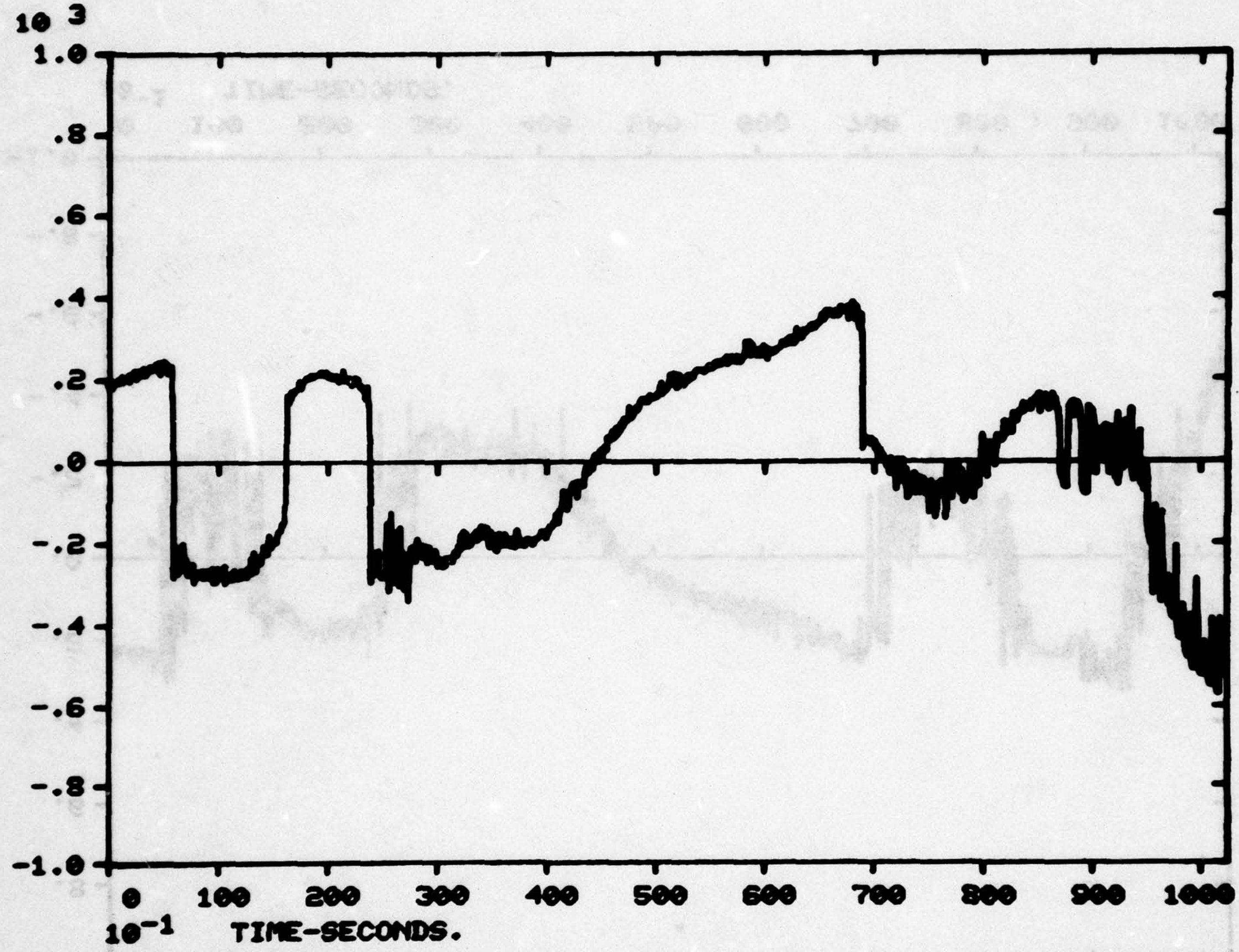


Figure B-64. Honeywell 45K Detrended Data, Scene 7

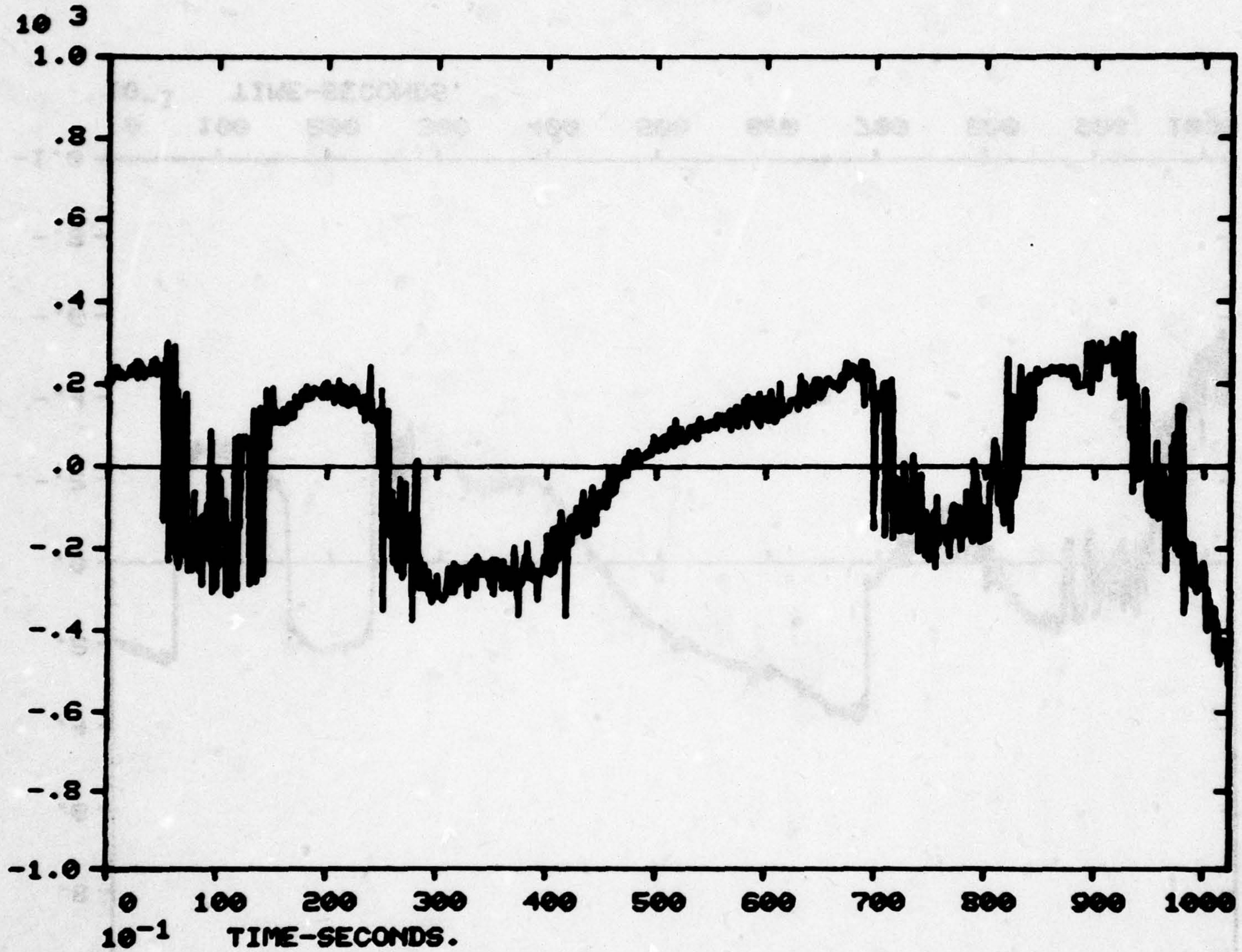


Figure B-65. Stewart-Warner 45K Detrended Data, Scene 7

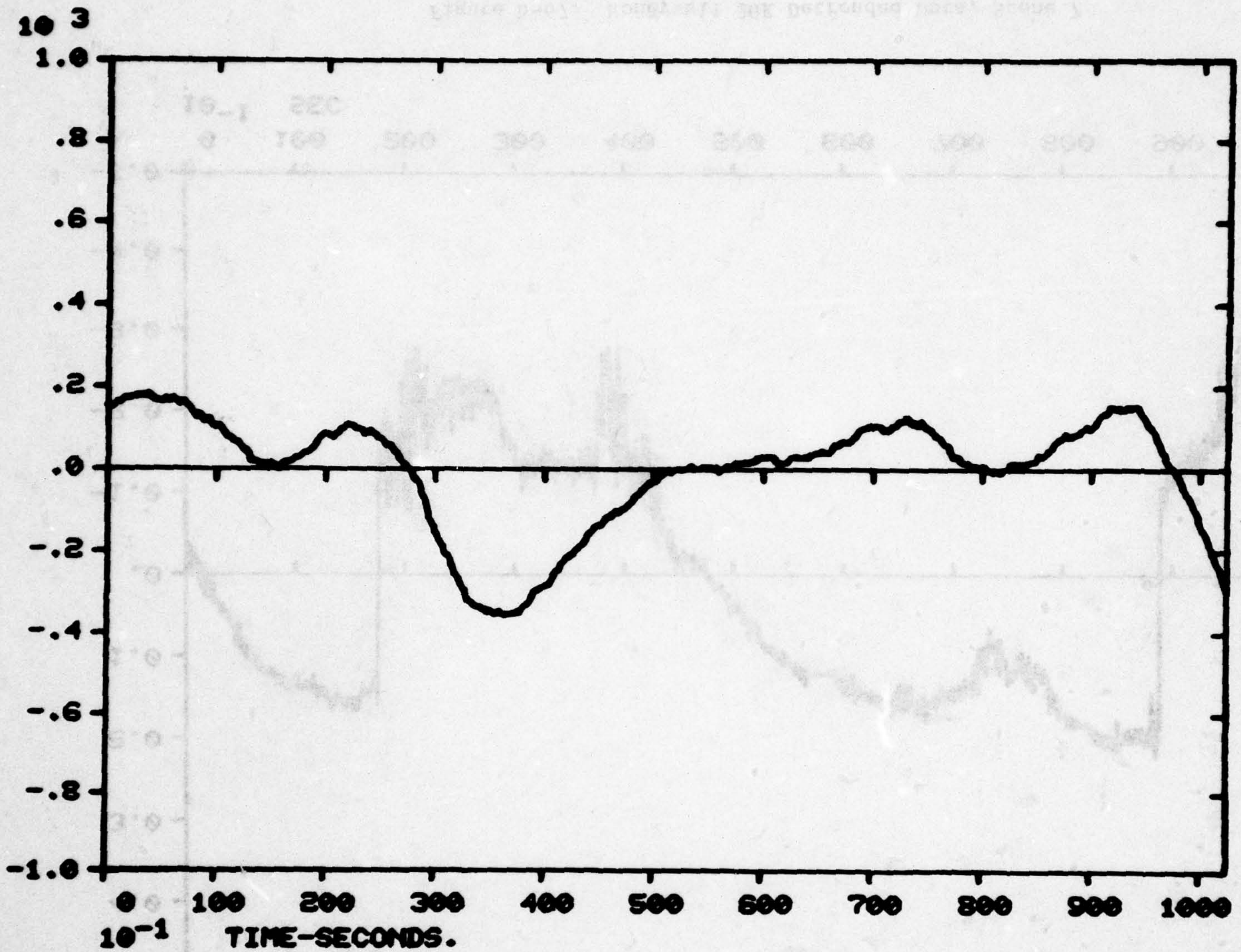


Figure B-66. Kollsman 45K Detrended Data, Scene 7

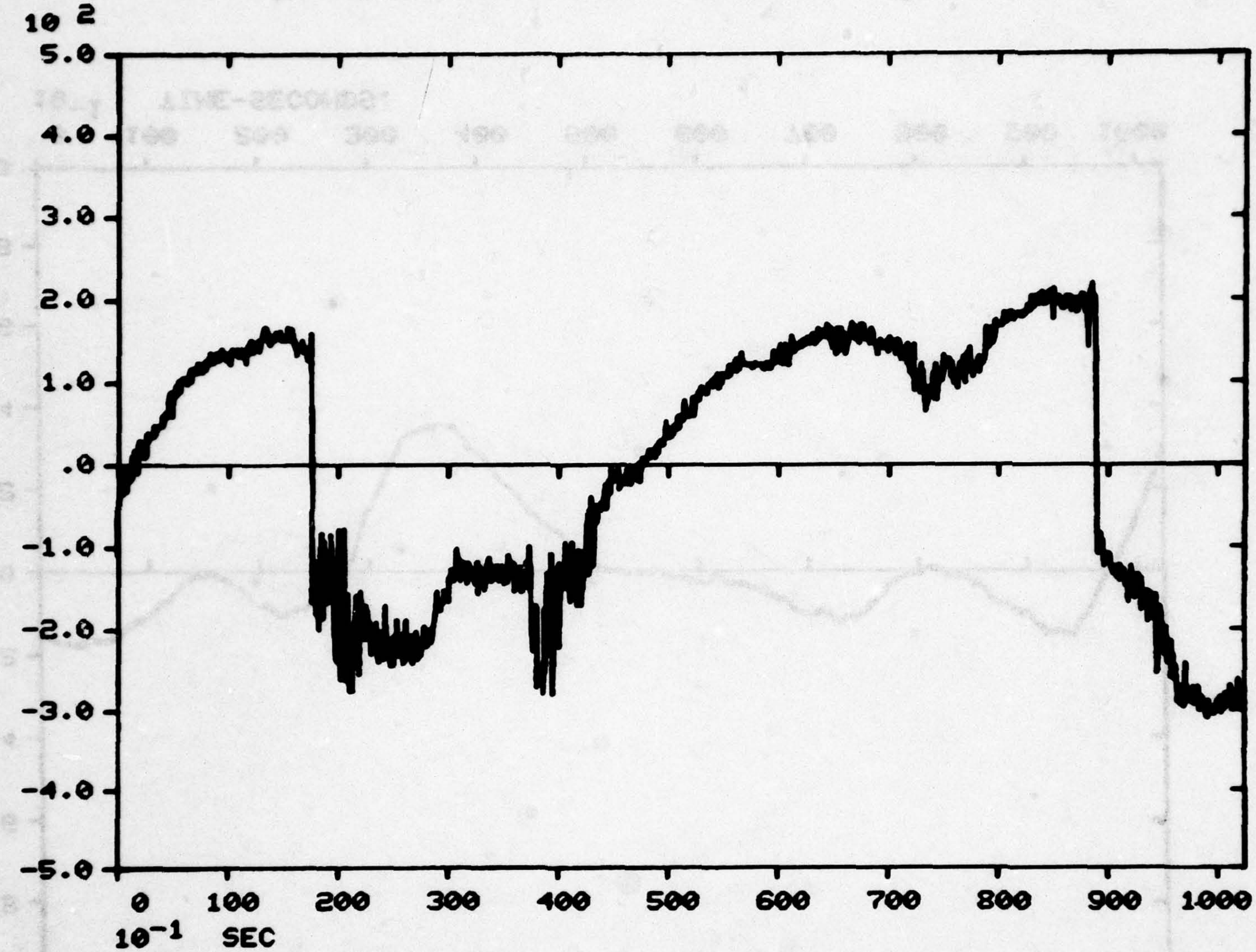


Figure B-67. Honeywell 20K Detrended Data, Scene 7

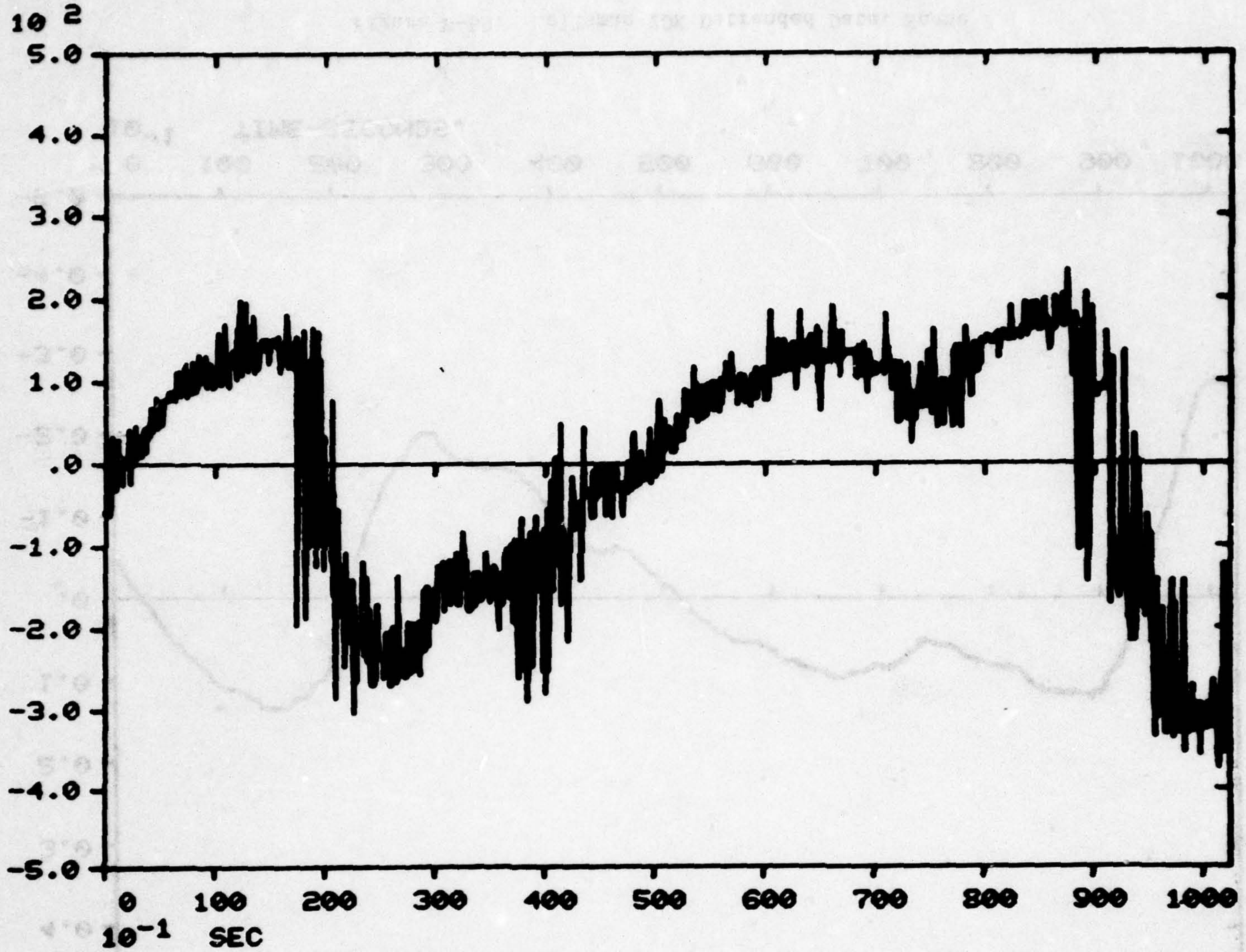


Figure B-68. Stewart-Warner 20K Detrended Data, Scene 7

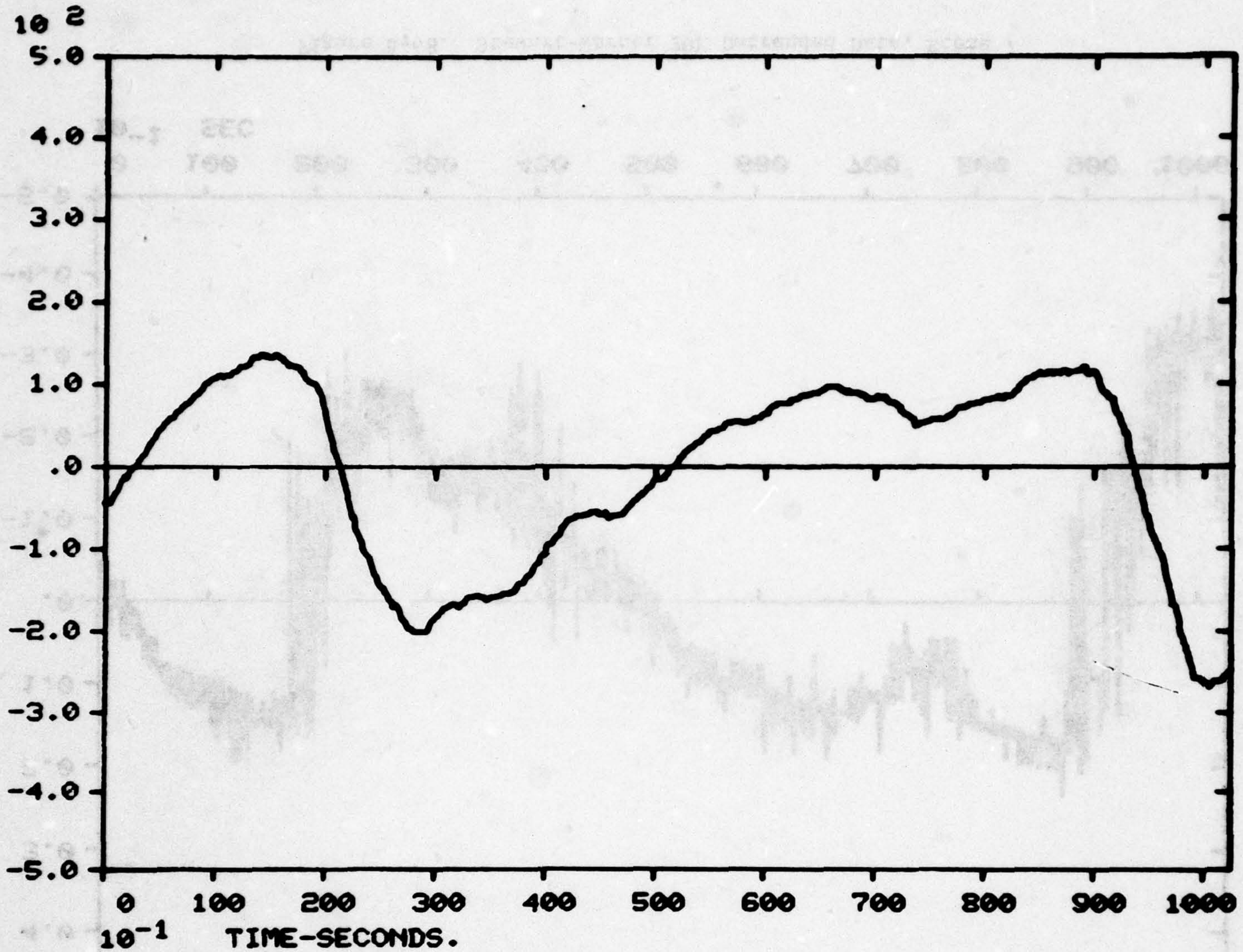


Figure B-69. Kollsman 20K Detrended Data, Scene 7

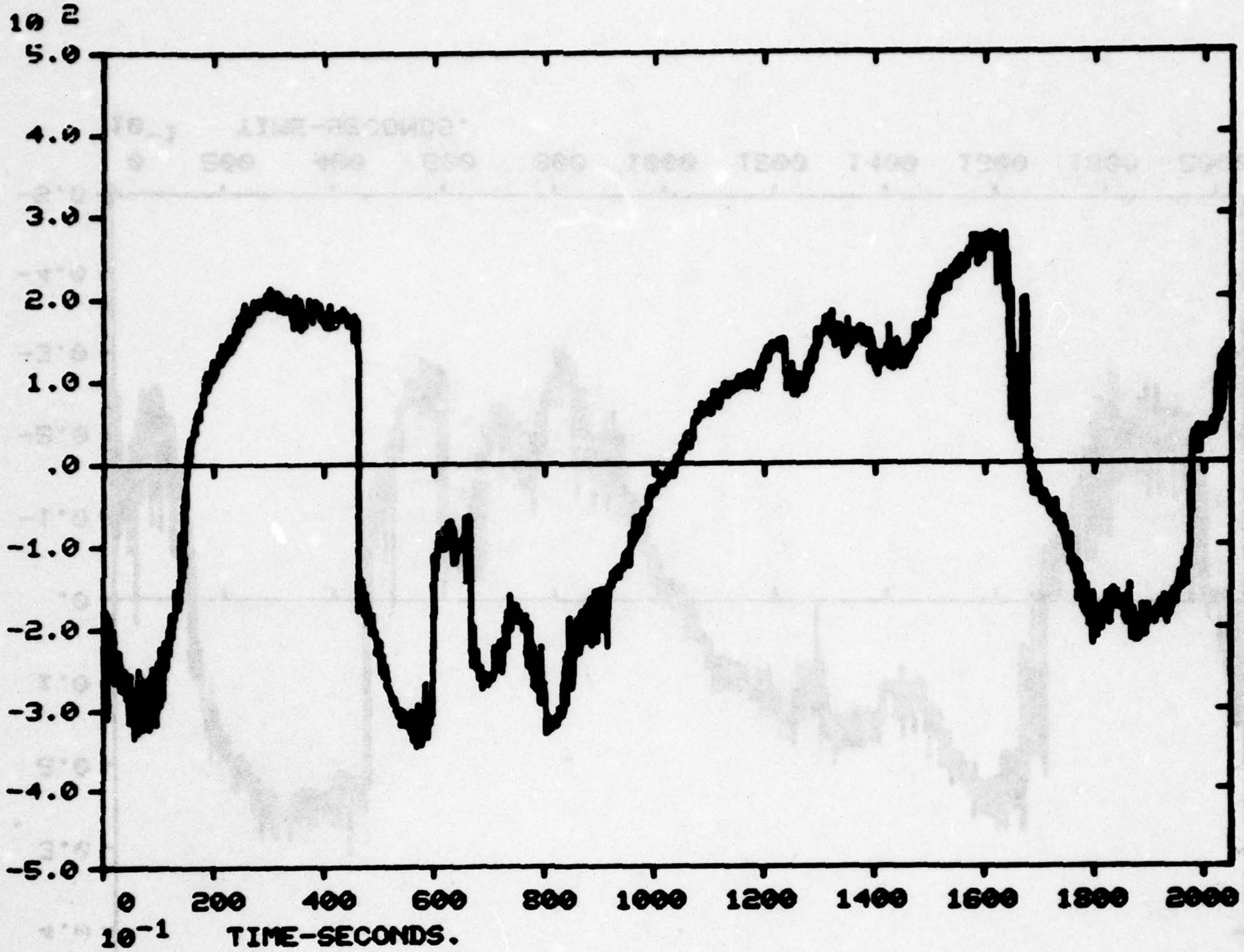


Figure B-70. Honeywell 10K Detrended Data, Scene 7

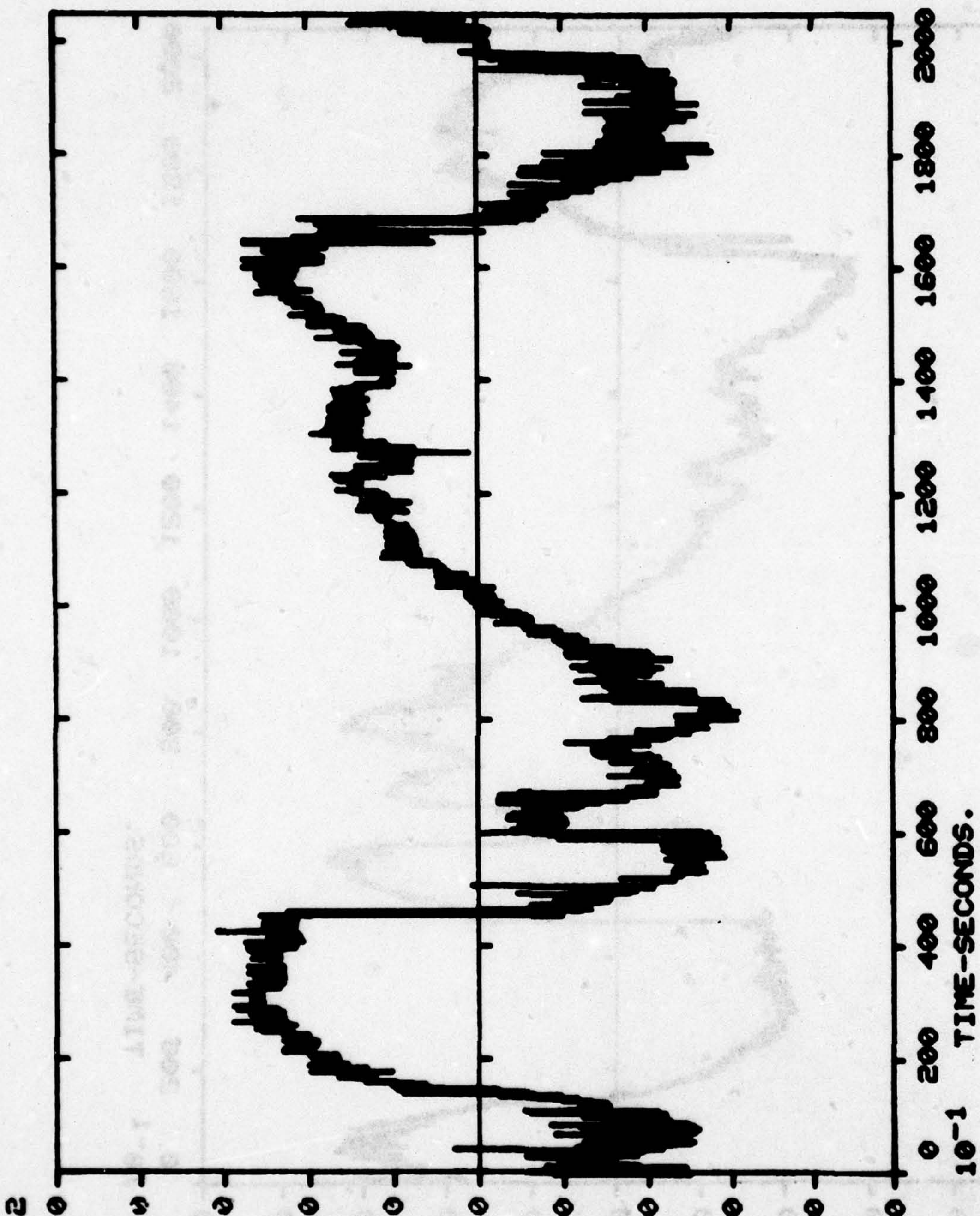


Figure B-71. Stewart-Warner 19K Detrended Data, Scene 7

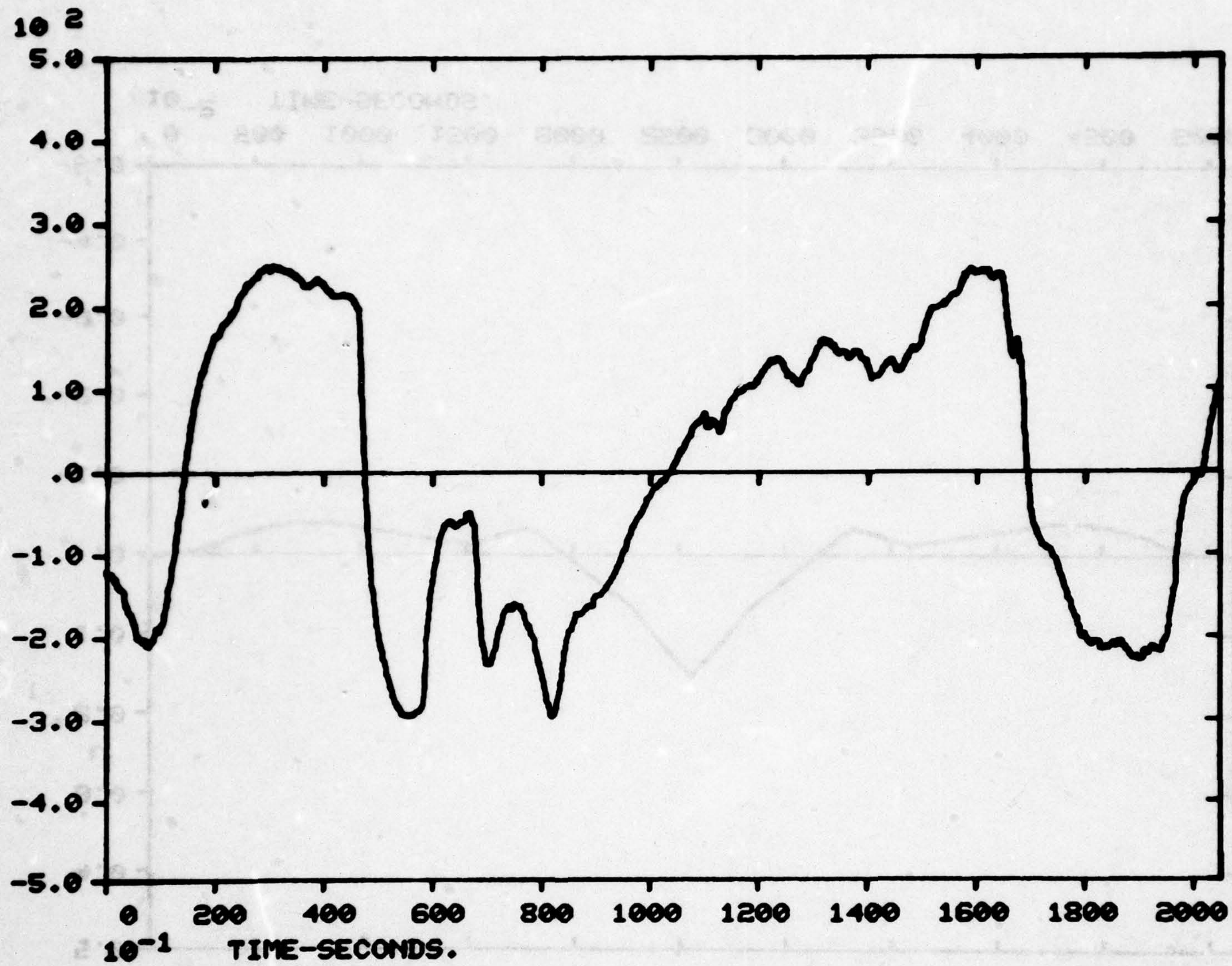


Figure B-72. Kollsman 10K Detrended Data, Scene 7

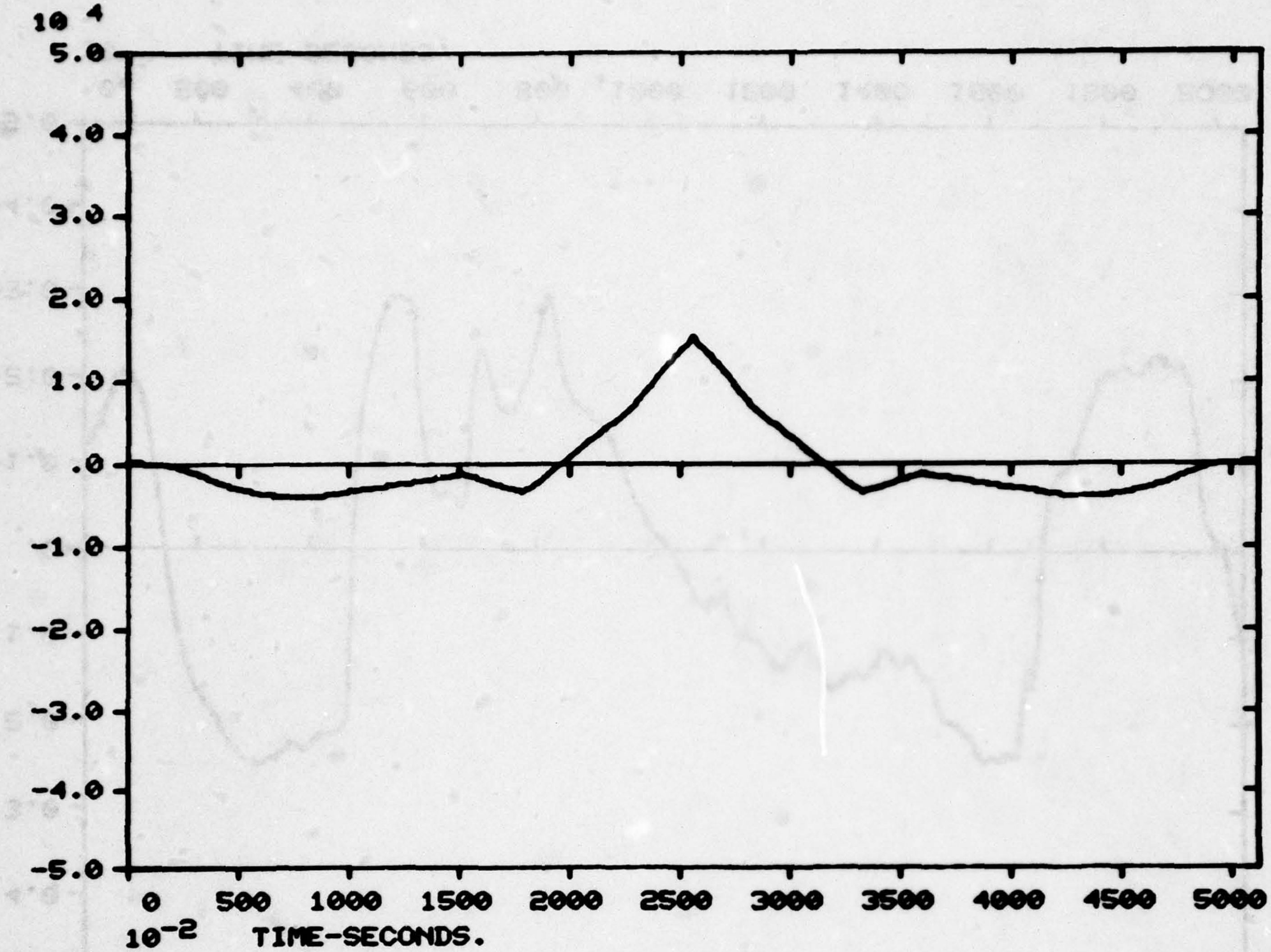


Figure B-73. Honeywell 63.5K Auto Correlation, Scene 7

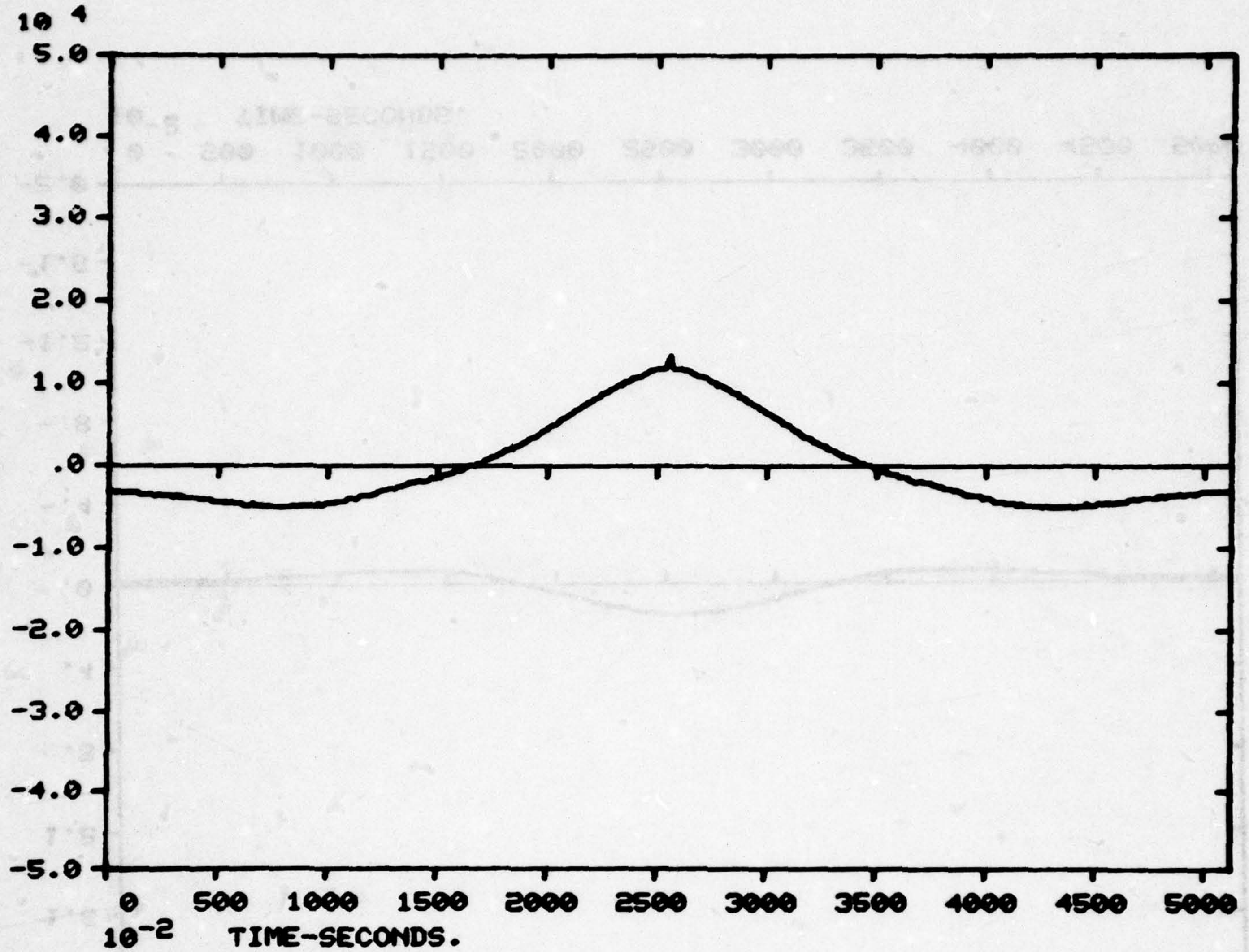


Figure B-74. Stewart-Warner 63.5K Auto Correlation, Scene 7

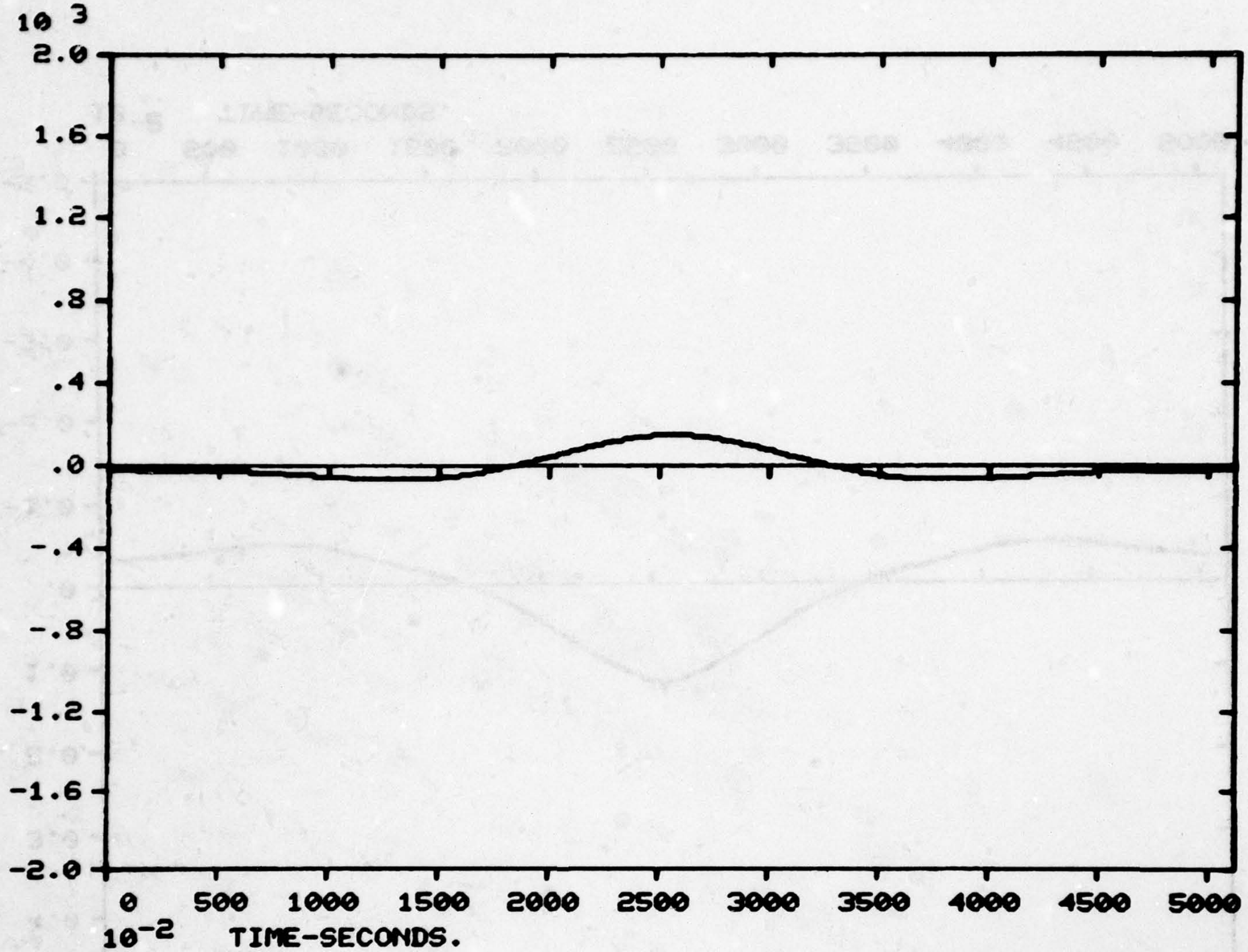


Figure B-75. Kollsman 63.5K Auto Correlation, Scene 7

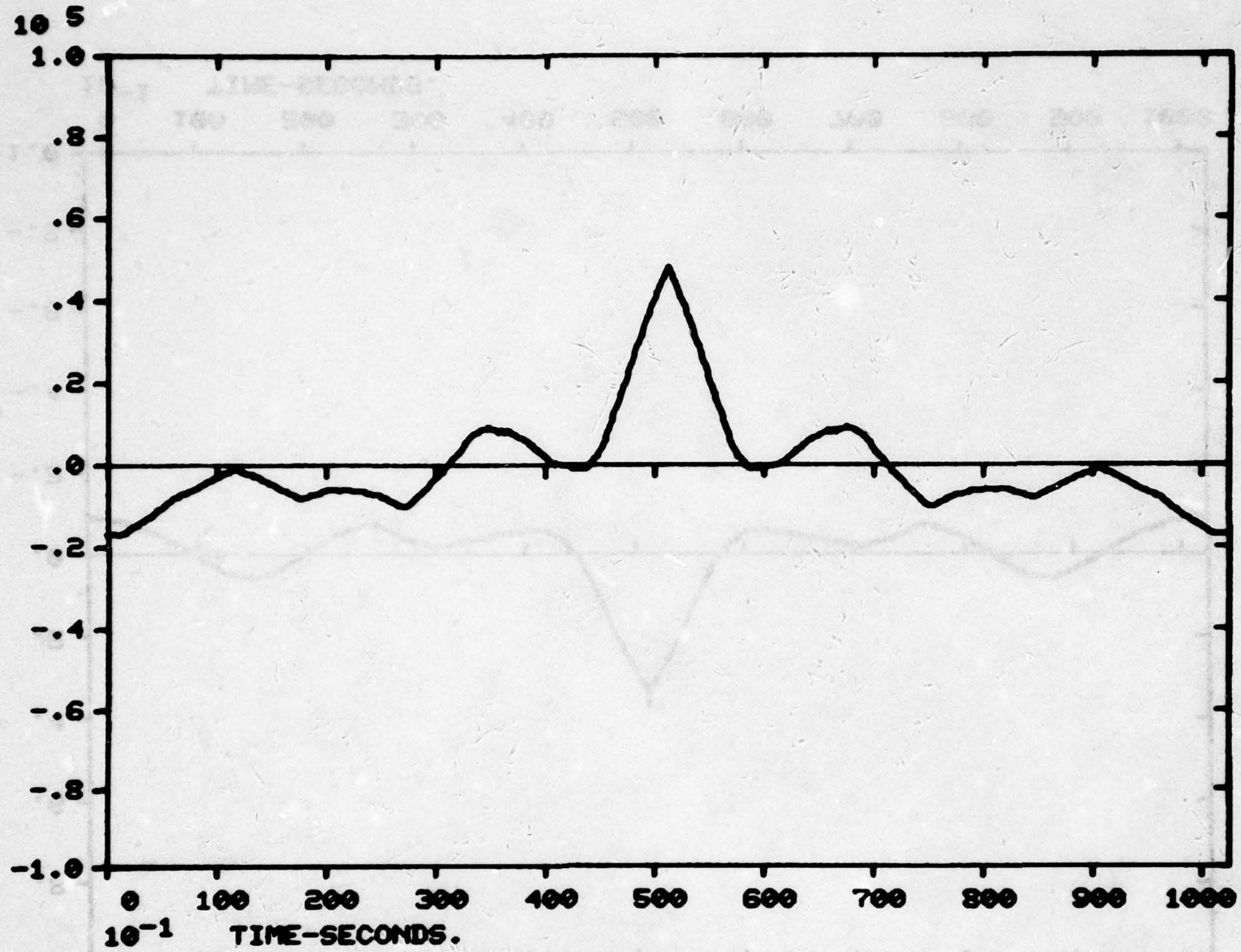


Figure B-76. Honeywell 45K Auto Correlation, Scene 7

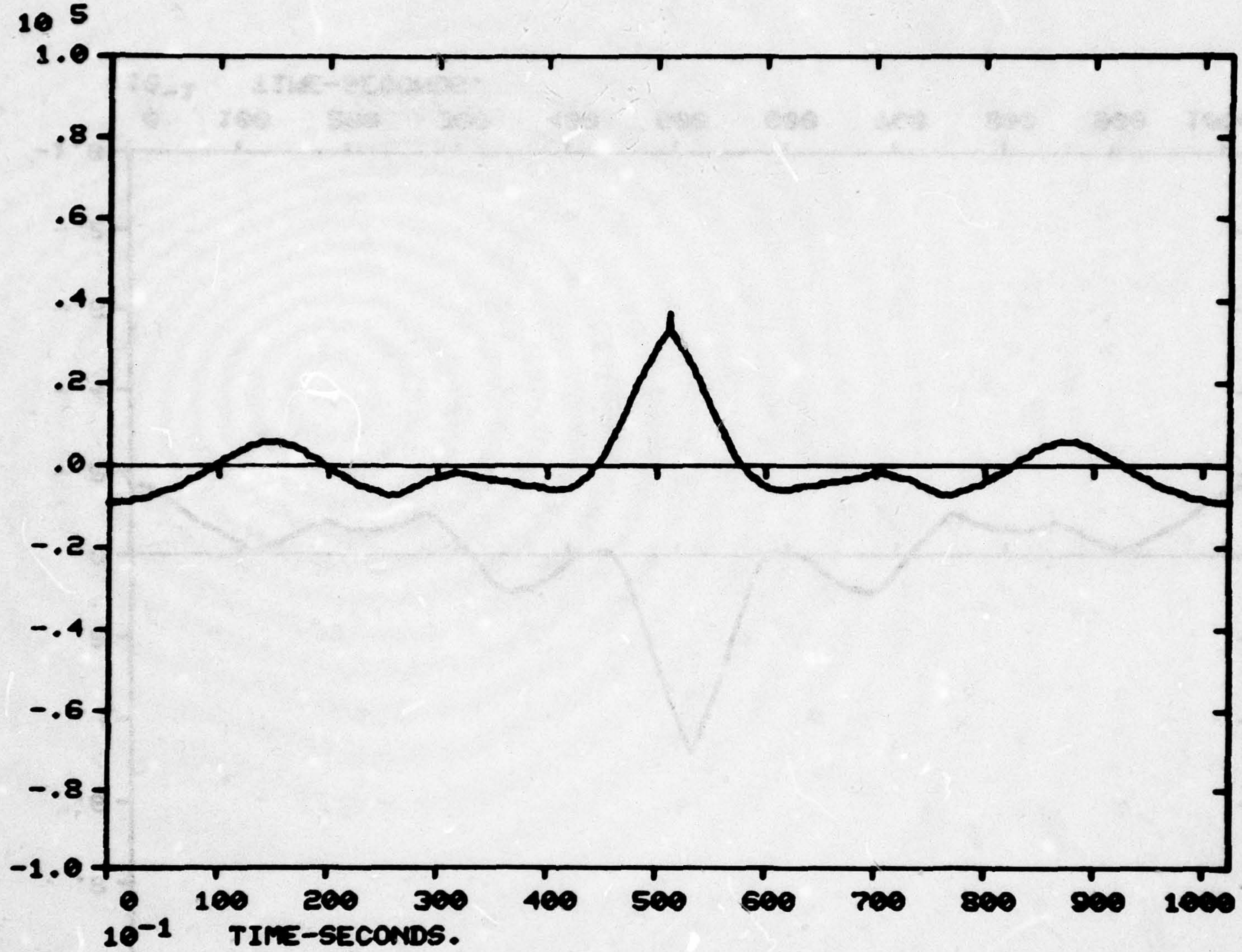


Figure B-77. Stewart-Warner 45K Auto Correlation, Scene 7

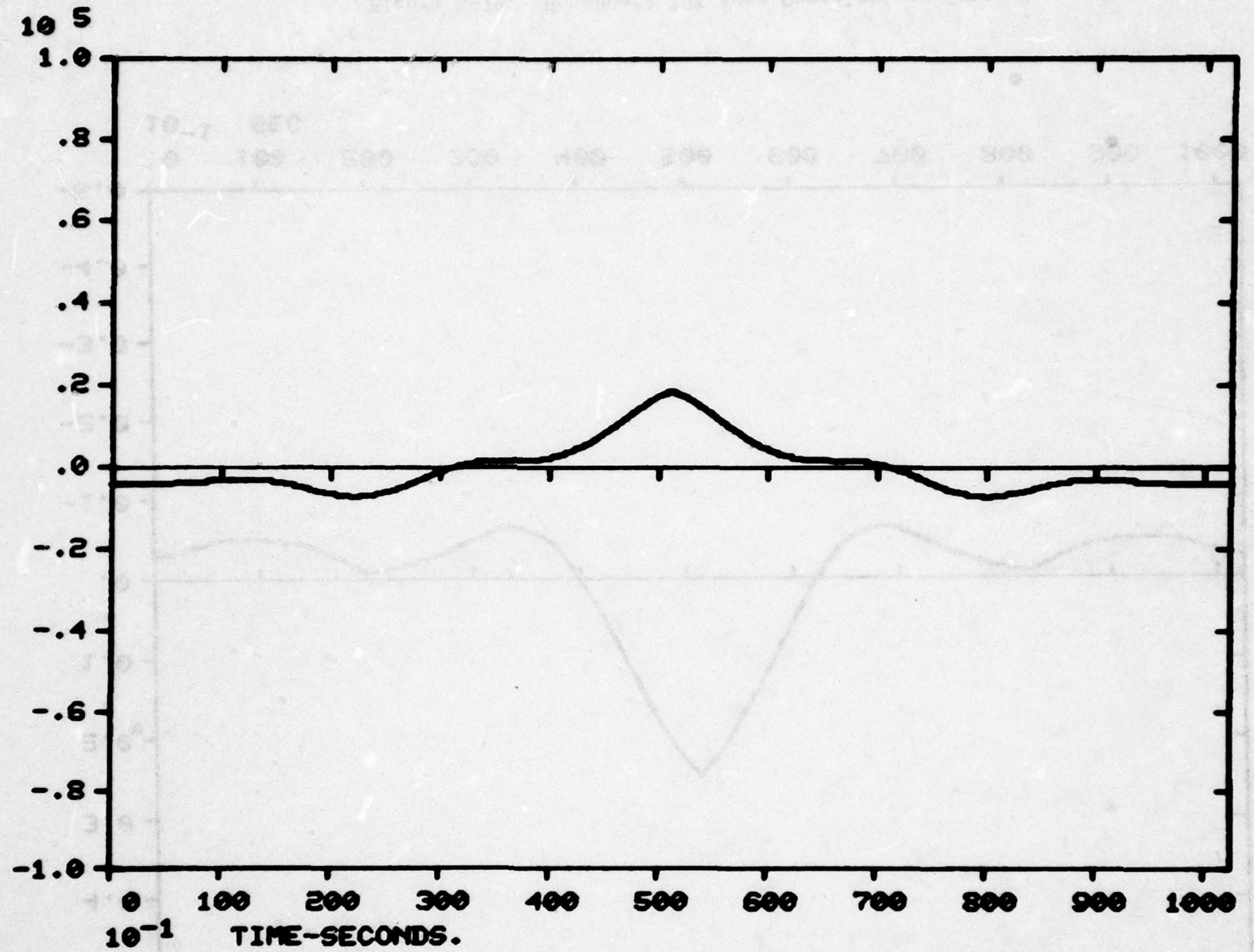


Figure B-78. Kollsman 45K Auto Correlation, Scene 7

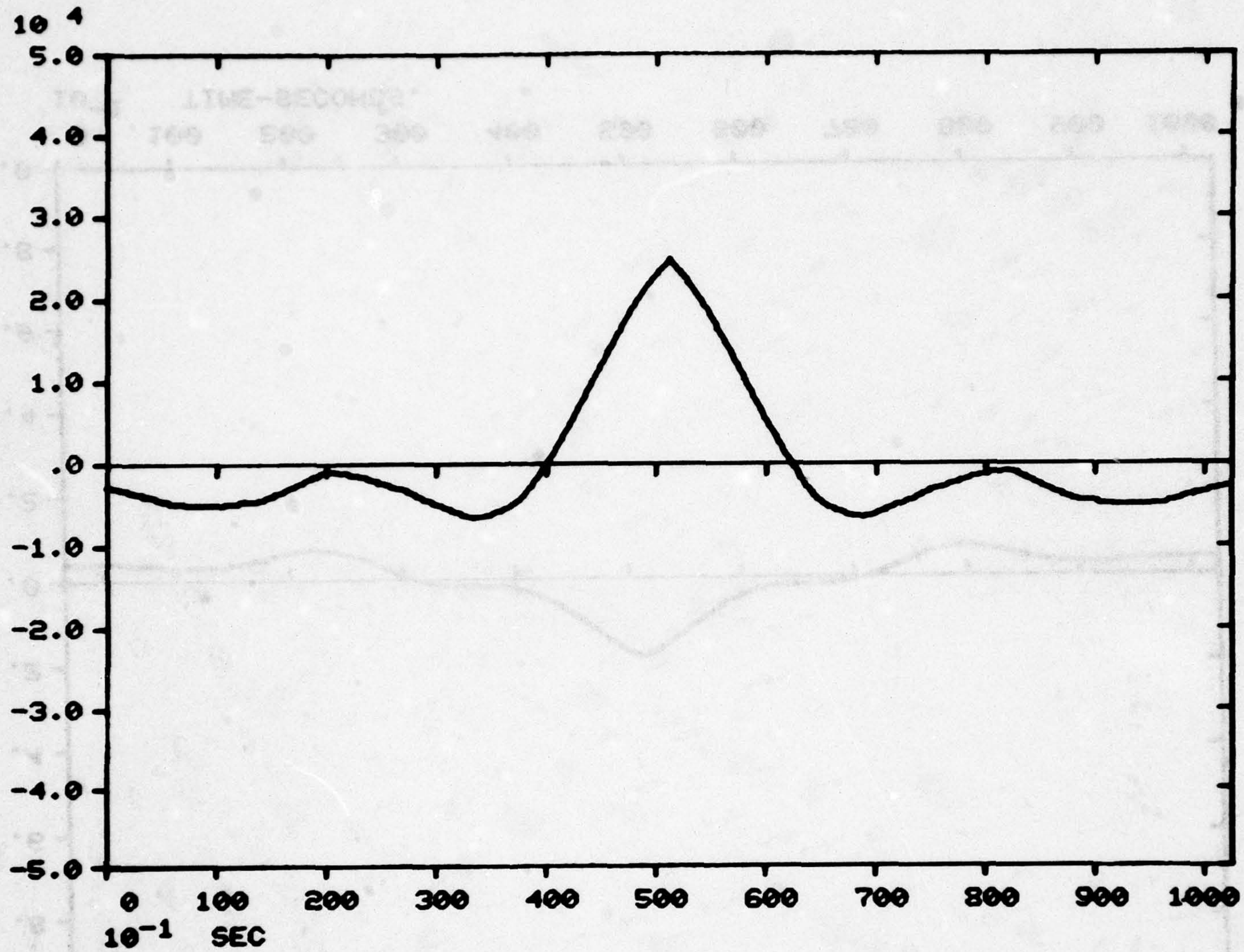


Figure B-79. Honeywell 20K Auto Correlation, Scene 7

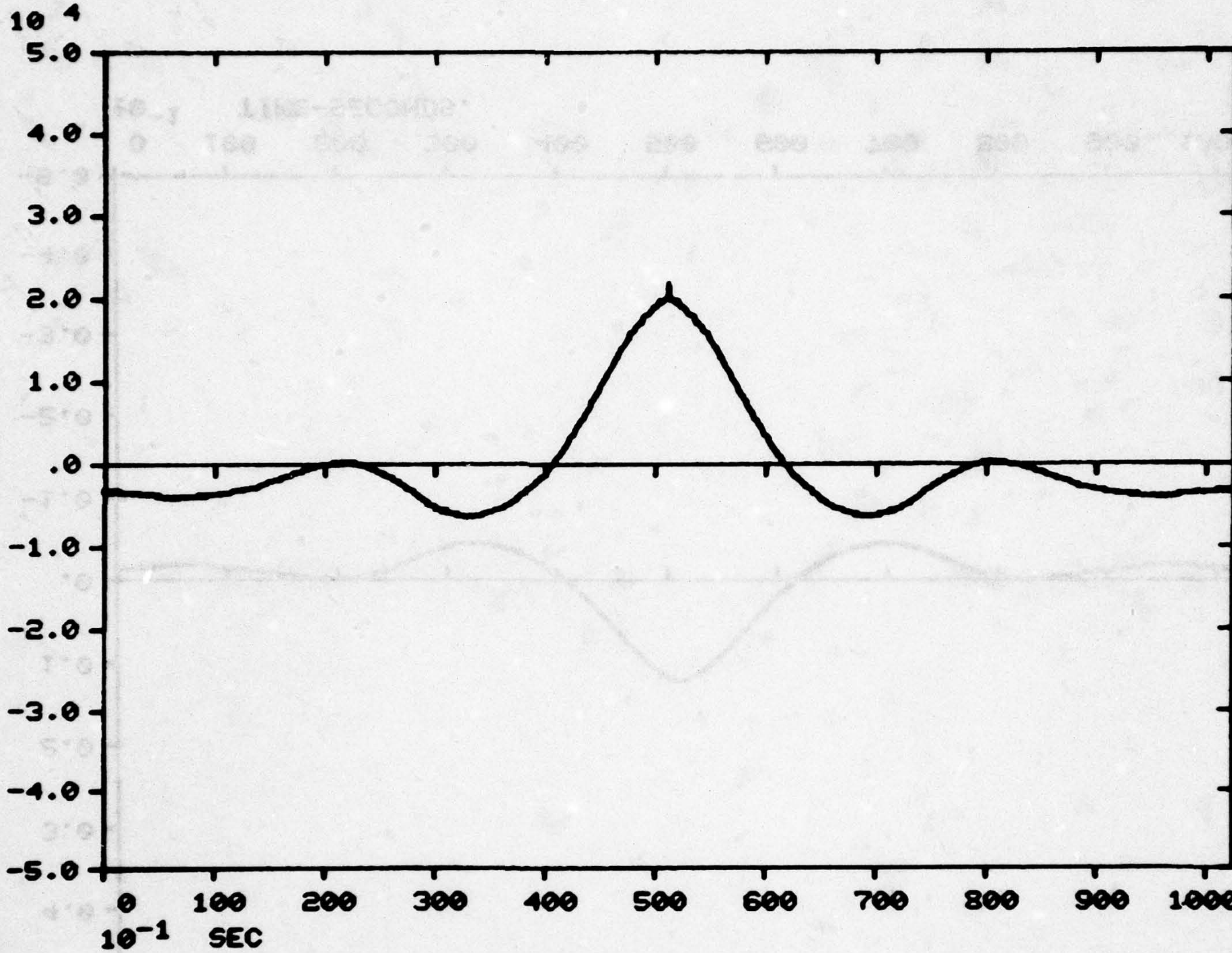


Figure B-80. Stewart-Warner 20K Auto Correlation, Scene 7

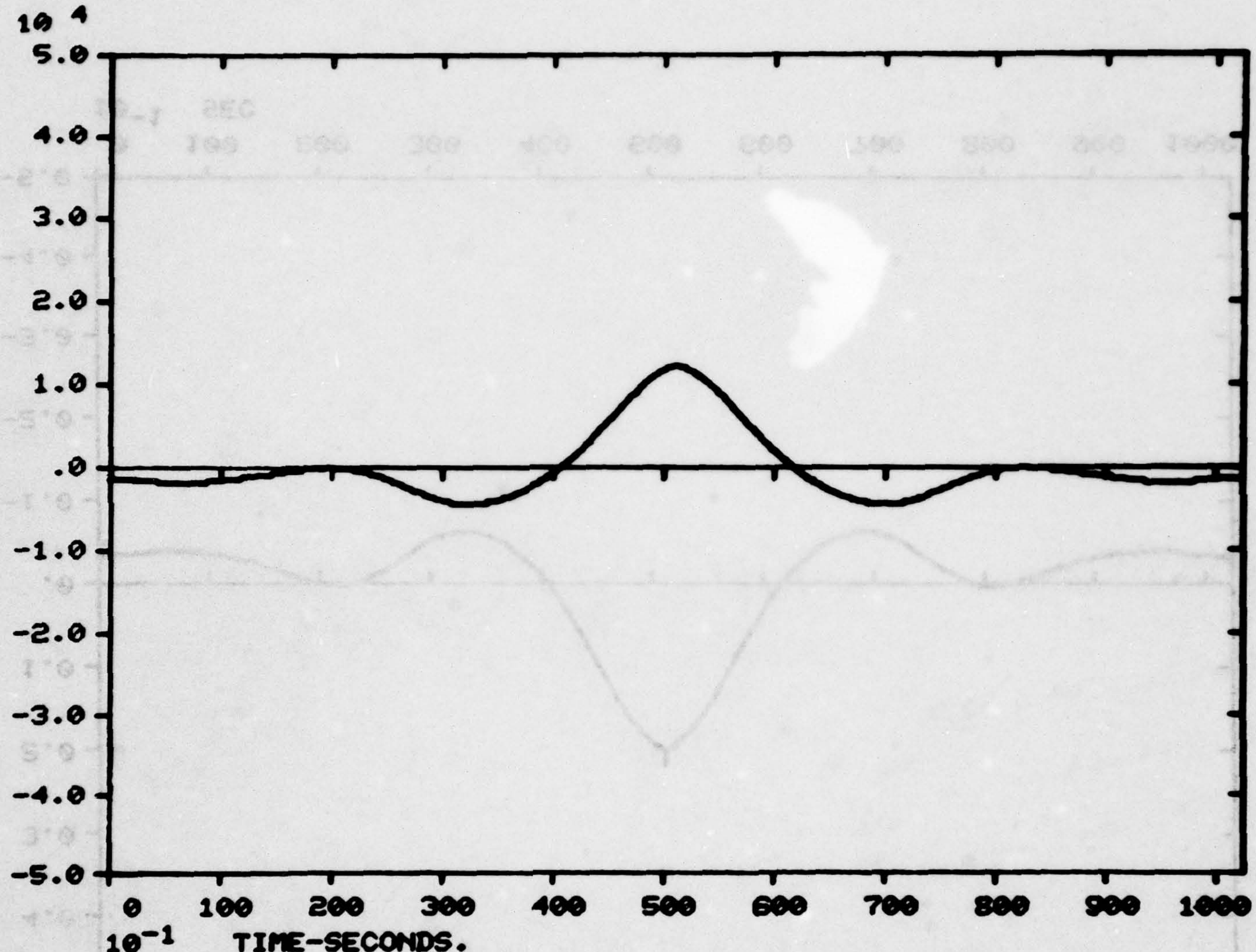


Figure B-81. Kollsman 20K Auto Correlation, Scene 7

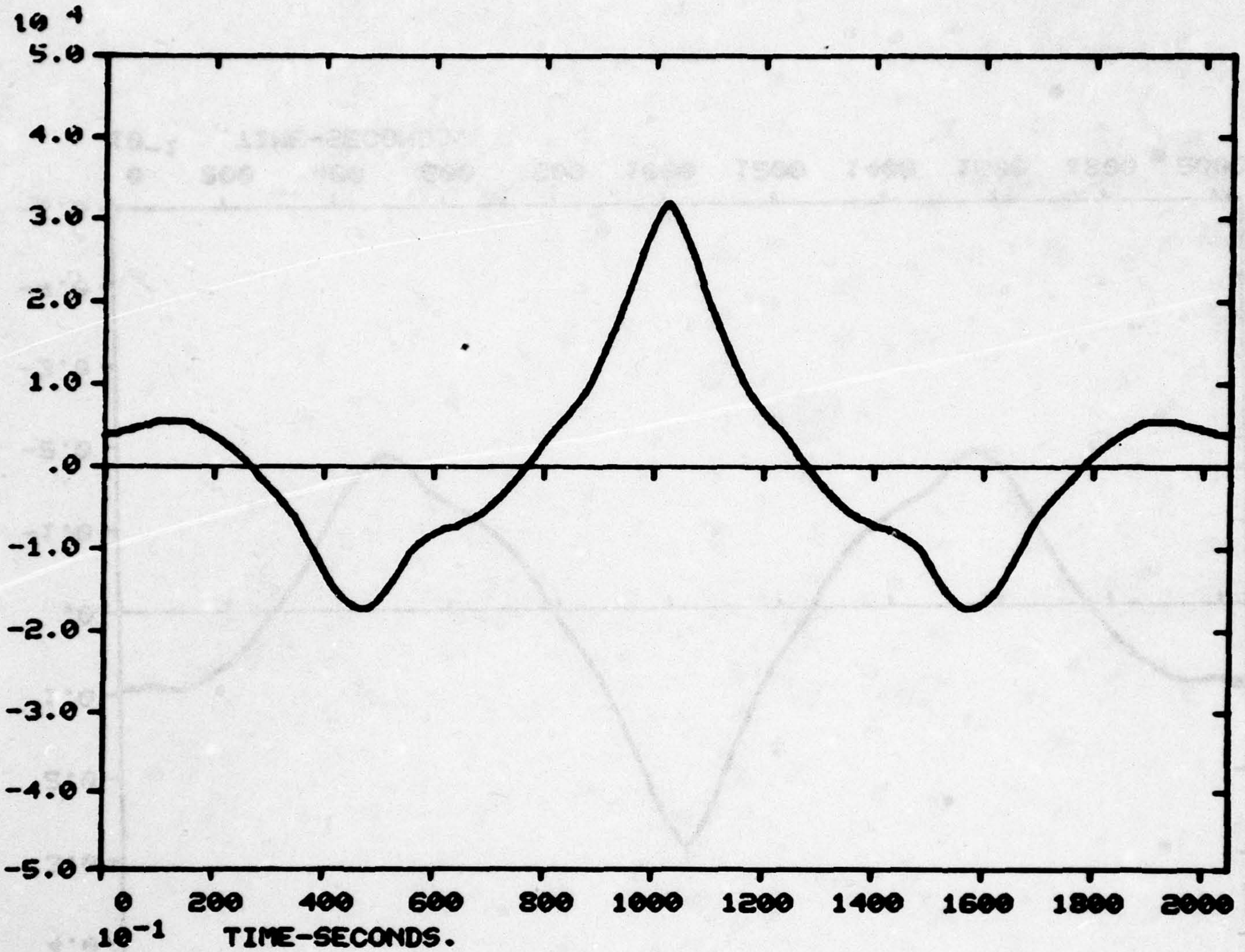


Figure B-82. Honeywell 10K Auto Correlation, Scene 7

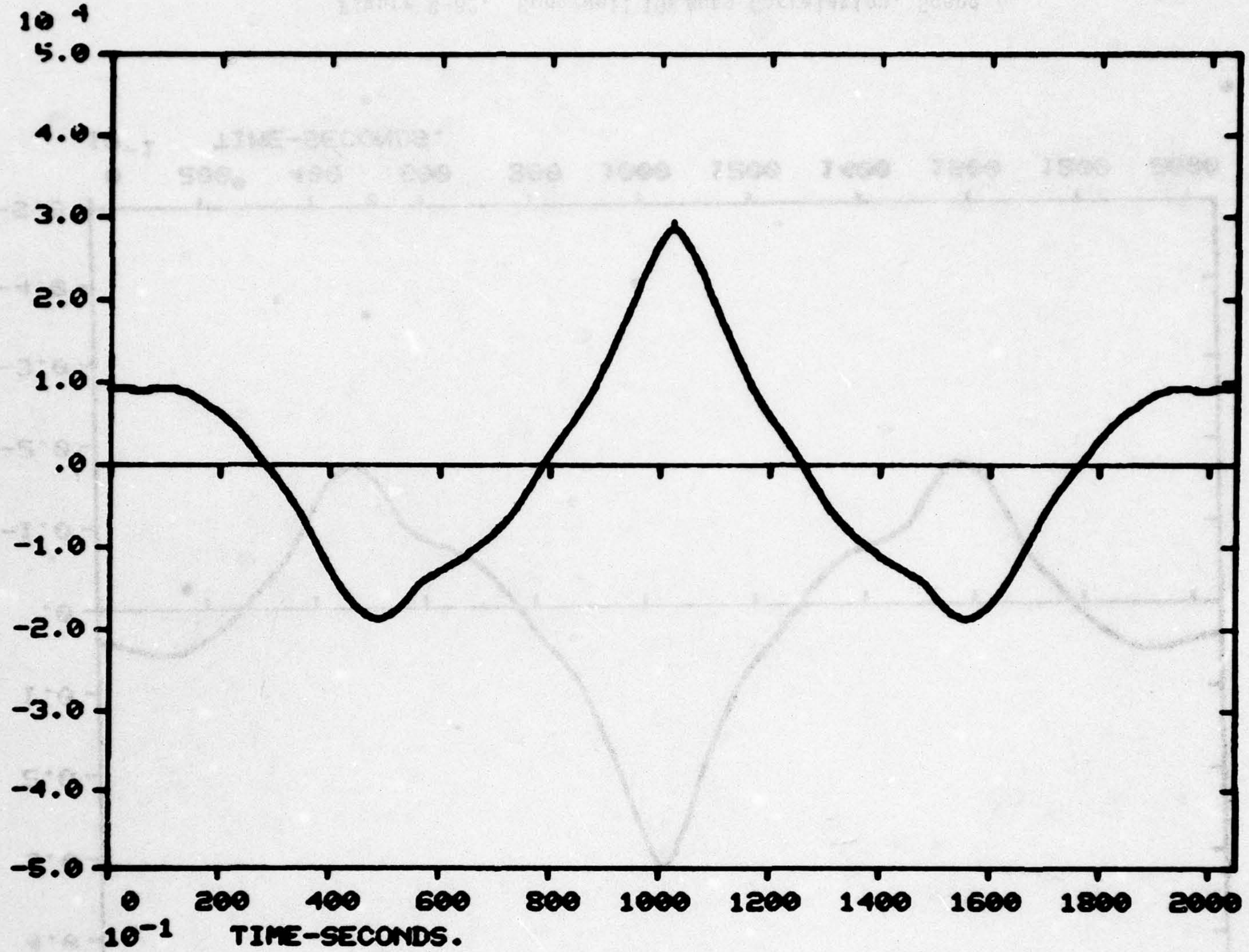


Figure B-83. Stewart-Warner 10K Auto Correlation, Scene 7

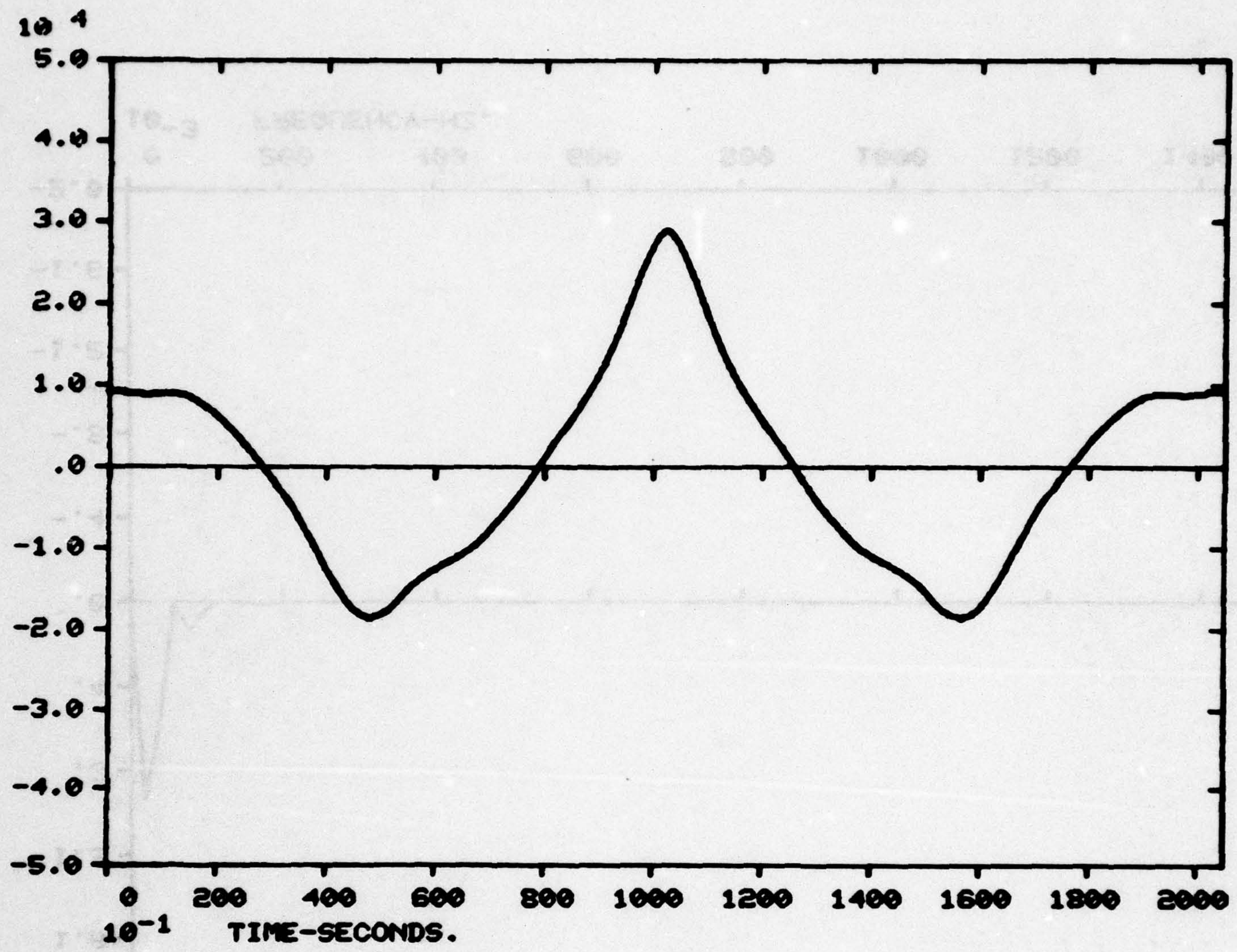


Figure B-84. Kollsman 10K Auto Correlation, Scene 7

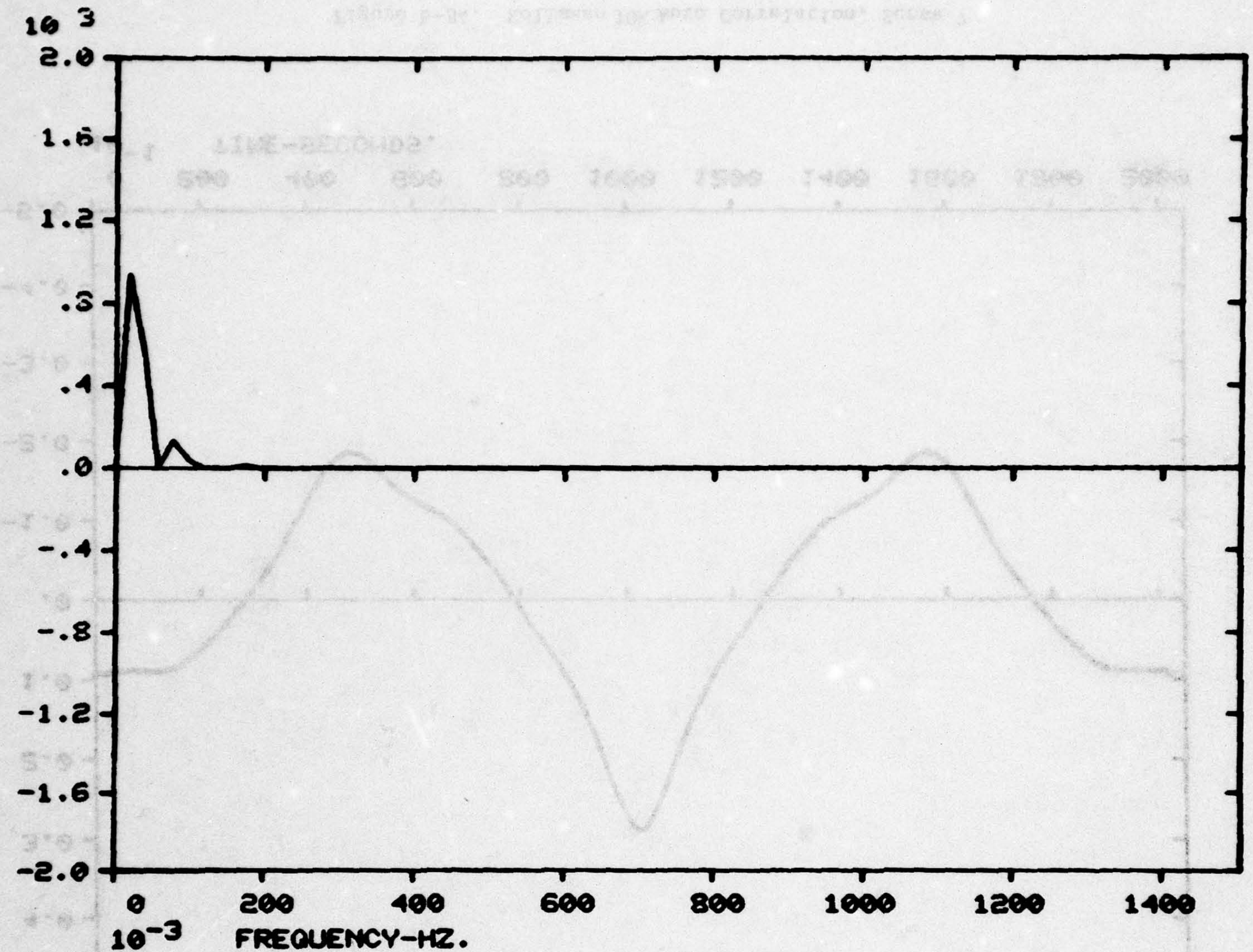


Figure B-85. Honeywell 63.5K PSD, Scene 7

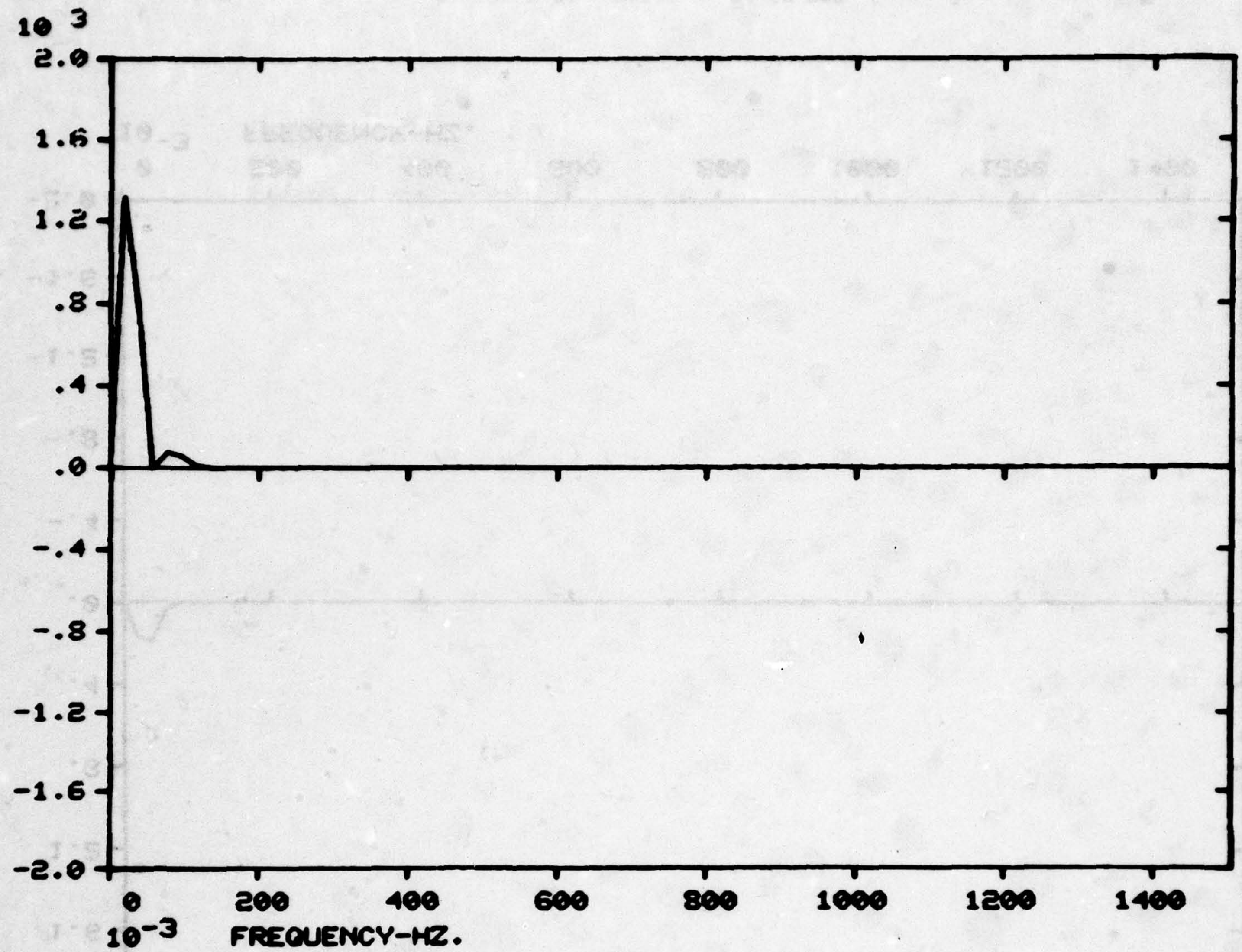


Figure B-86. Stewart-Warner 63.5K PSD, Scene 7

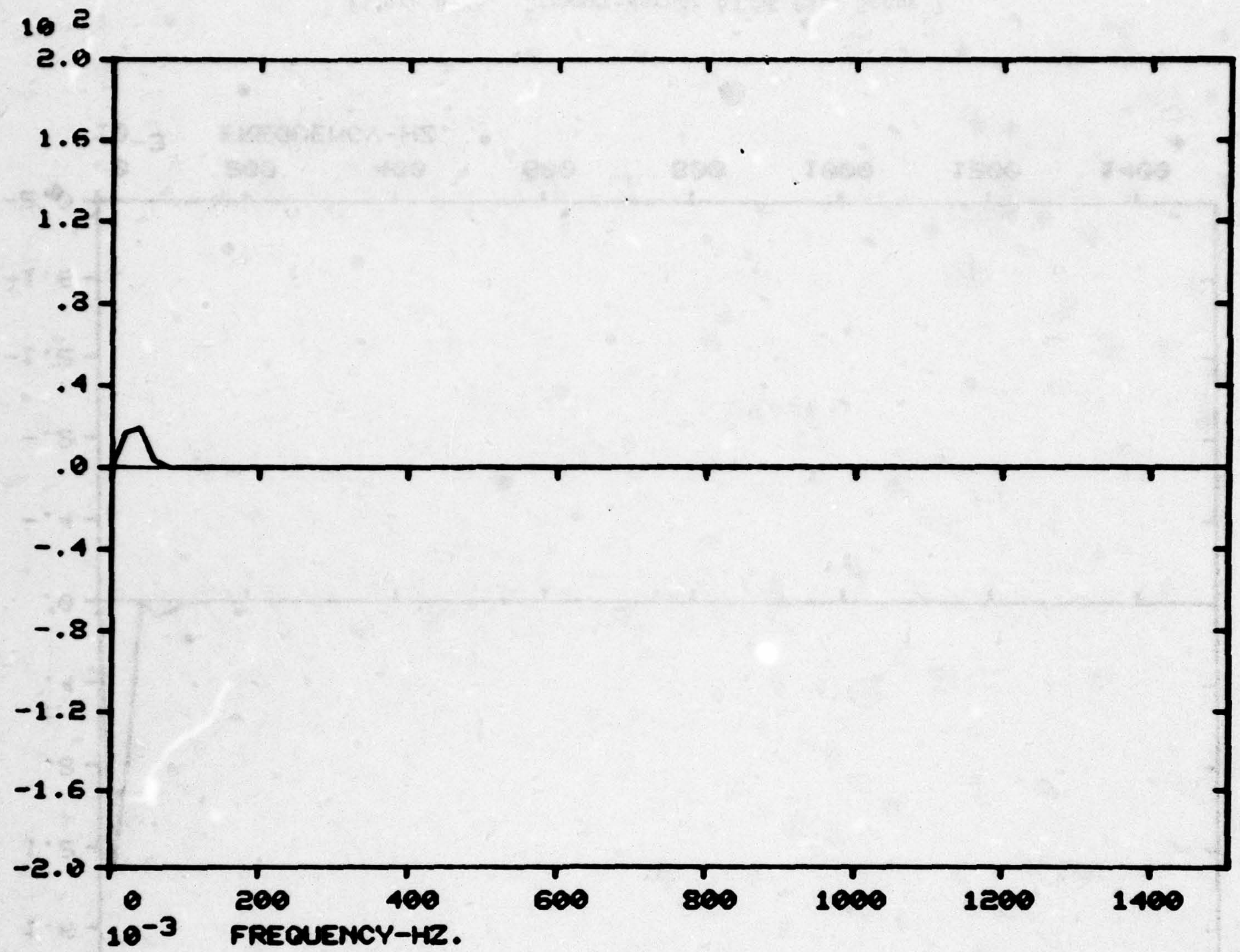


Figure B-87. Kollsman 63.5K PSD, Scene 7

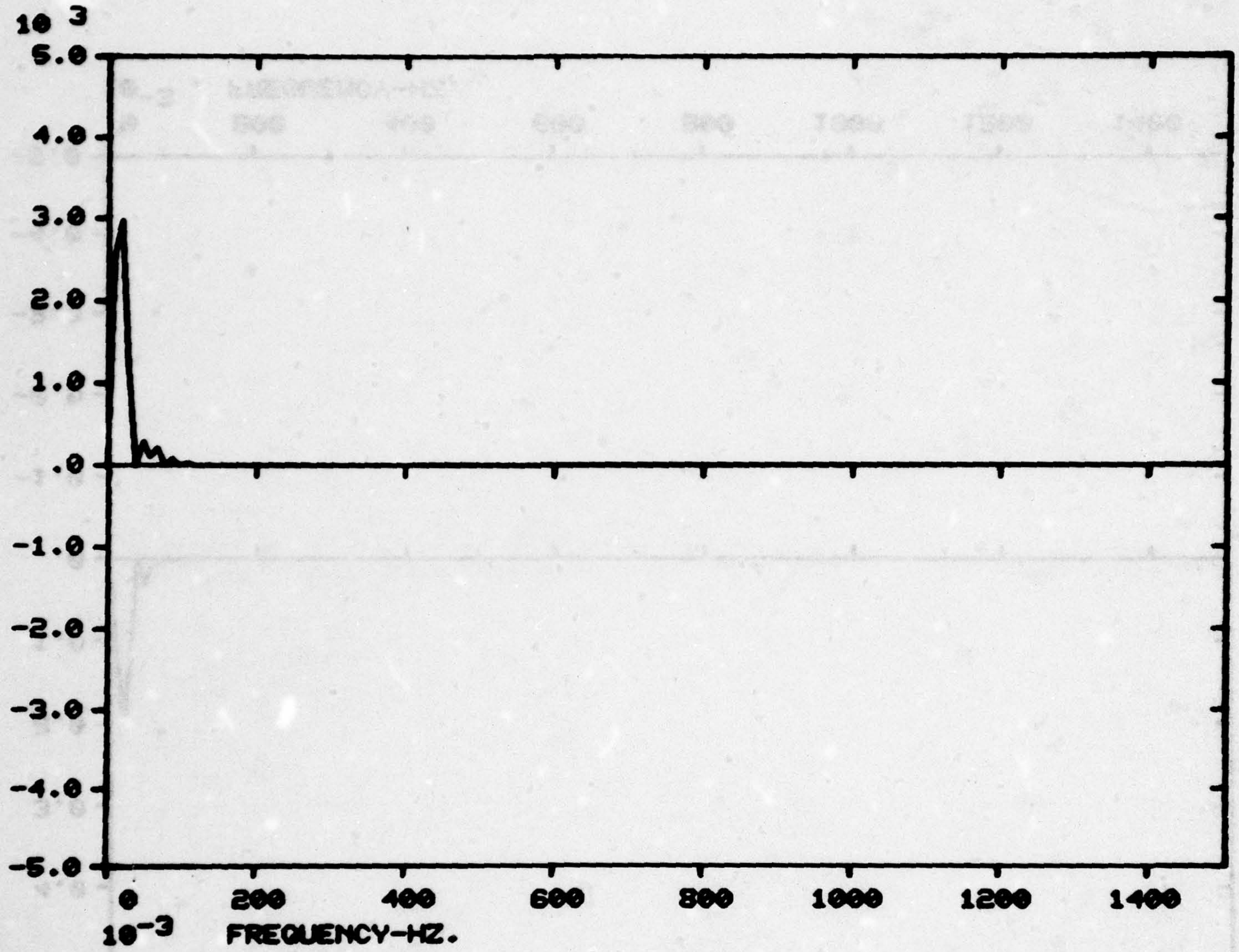


Figure B-88. Honeywell 45K PSD, Scene 7

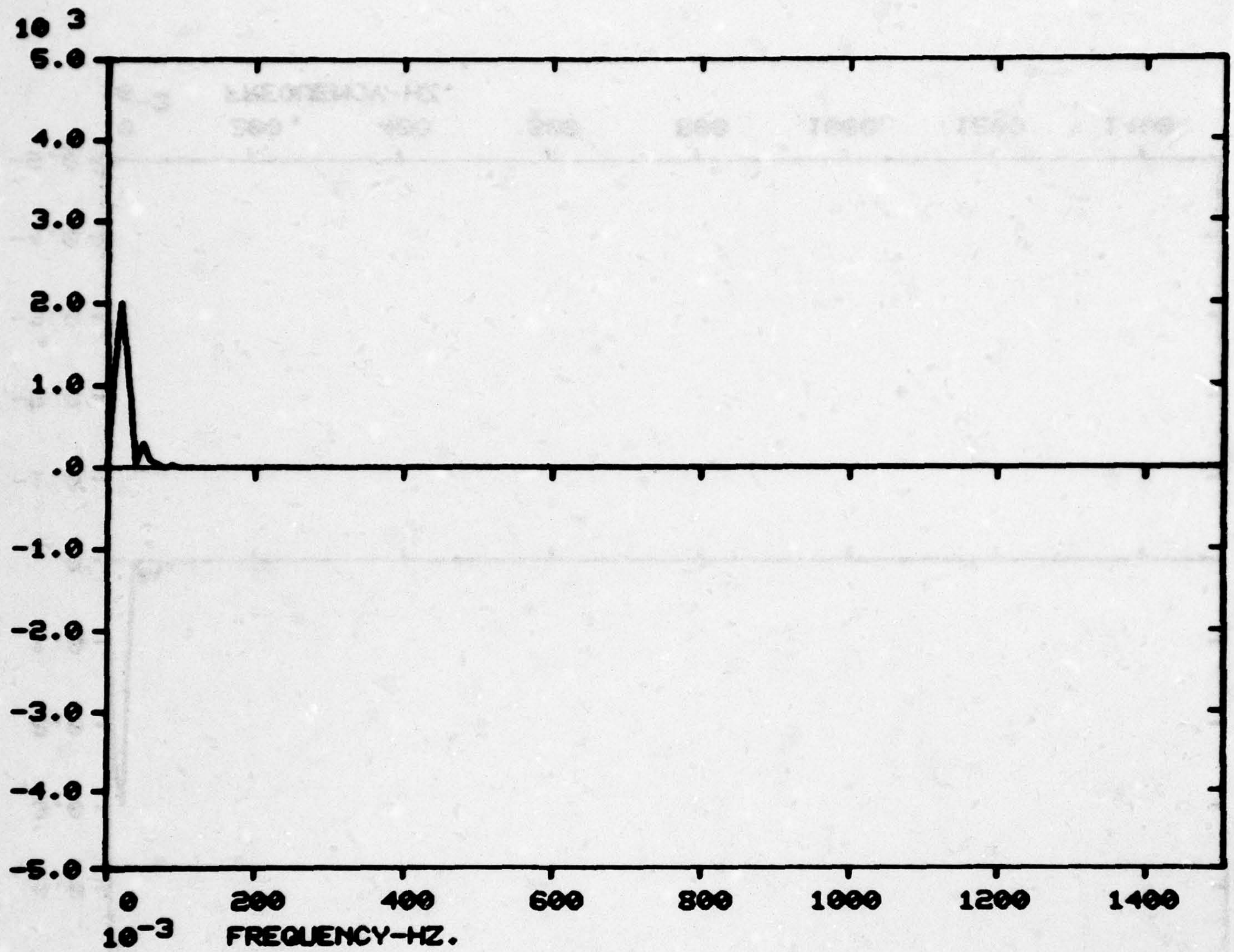


Figure B-89. Stewart-Warner 45K PSD, Scene 7

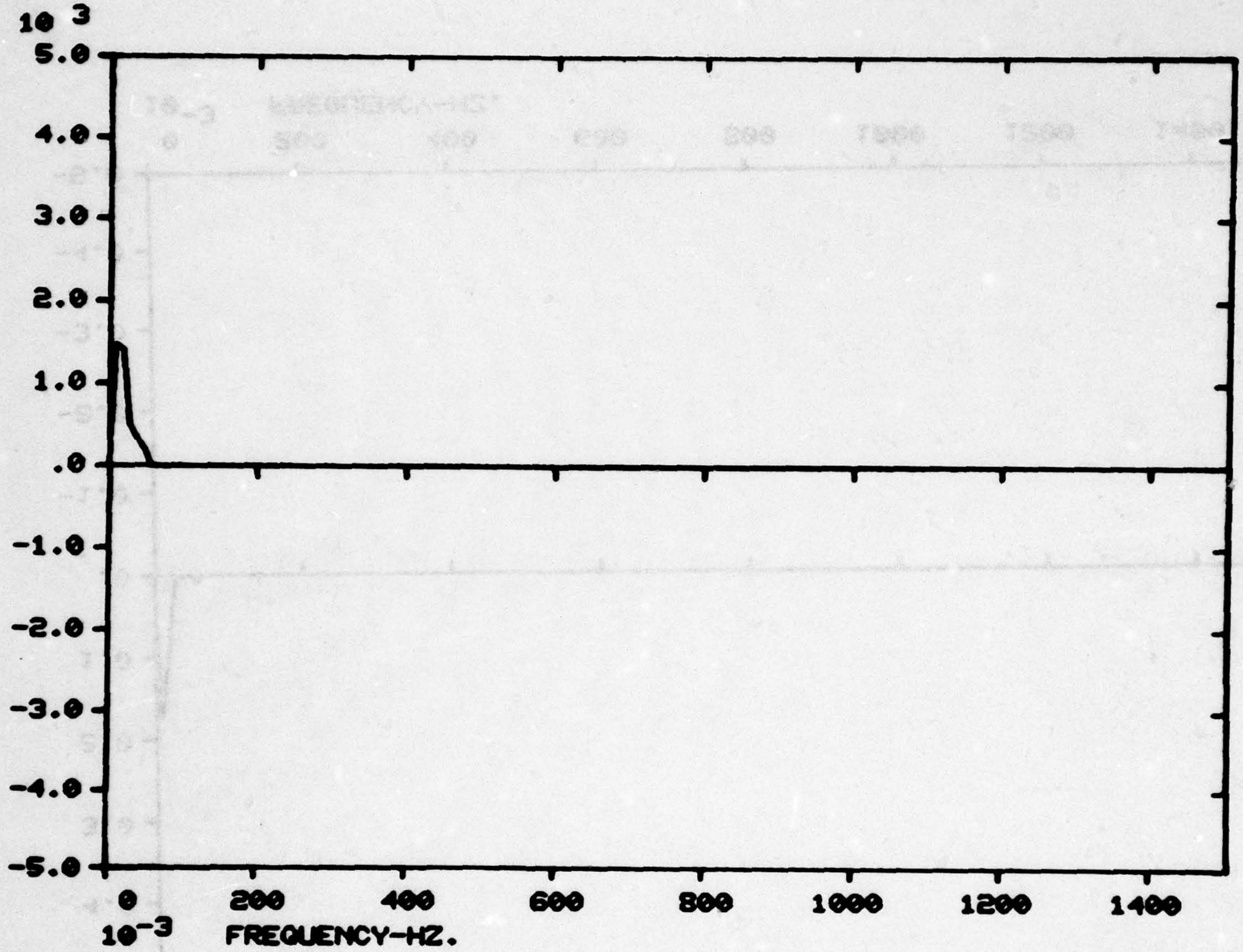


Figure B-90. Kollsman 45K PSD, Scene 7

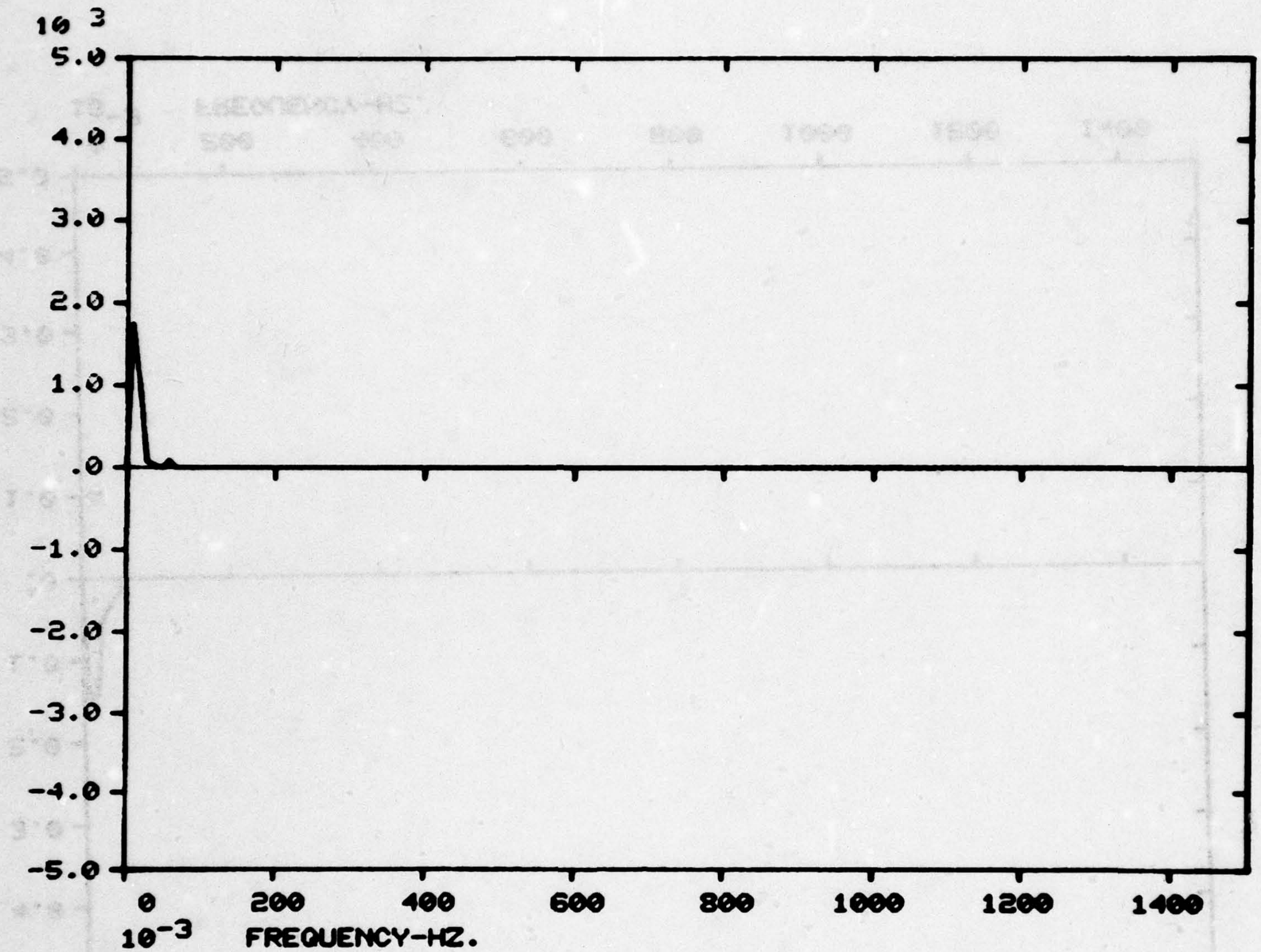


Figure B-91. Honeywell 20K PSD, Scene 7

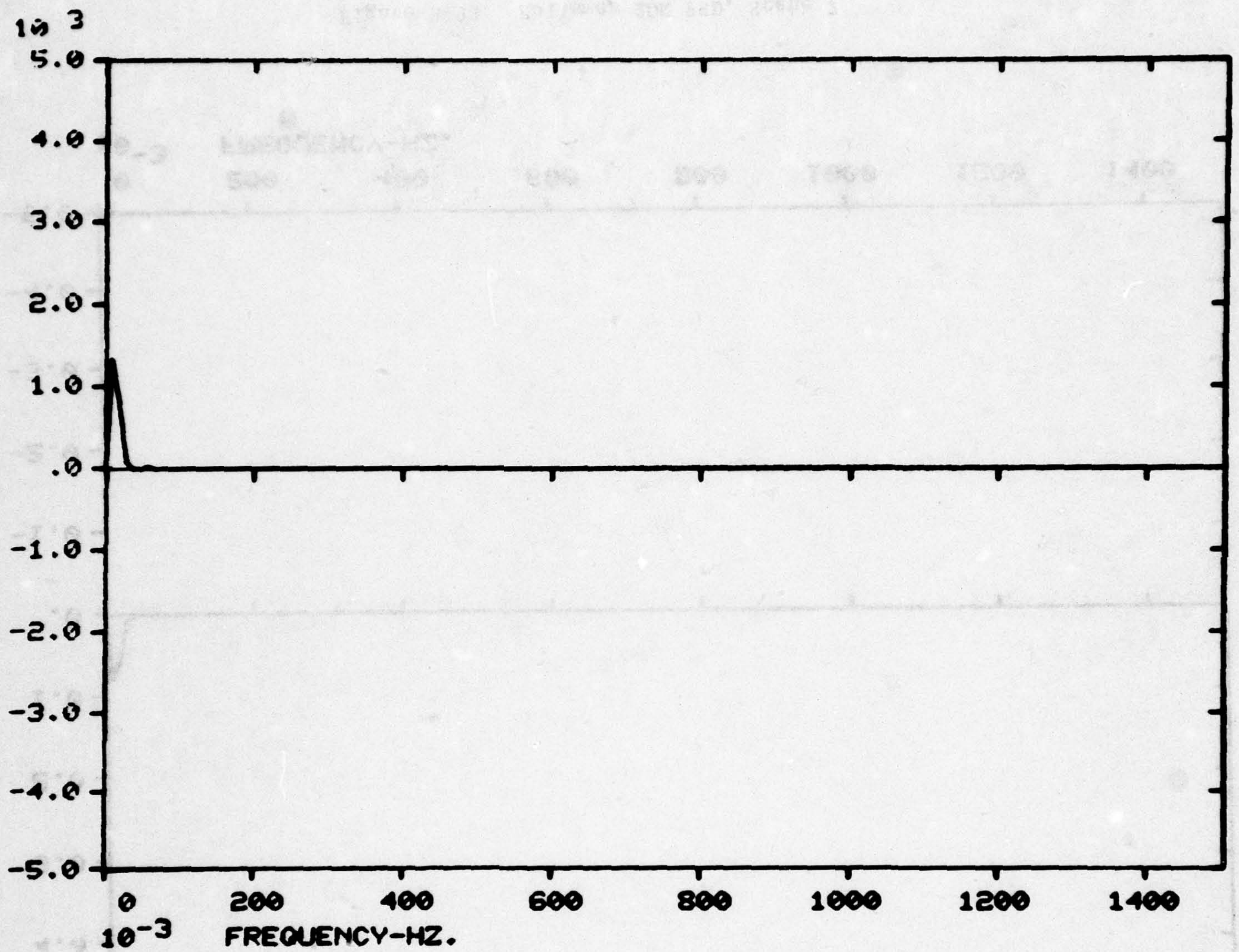


Figure B-92. Stewart-Warner 20K PSD, Scene 7

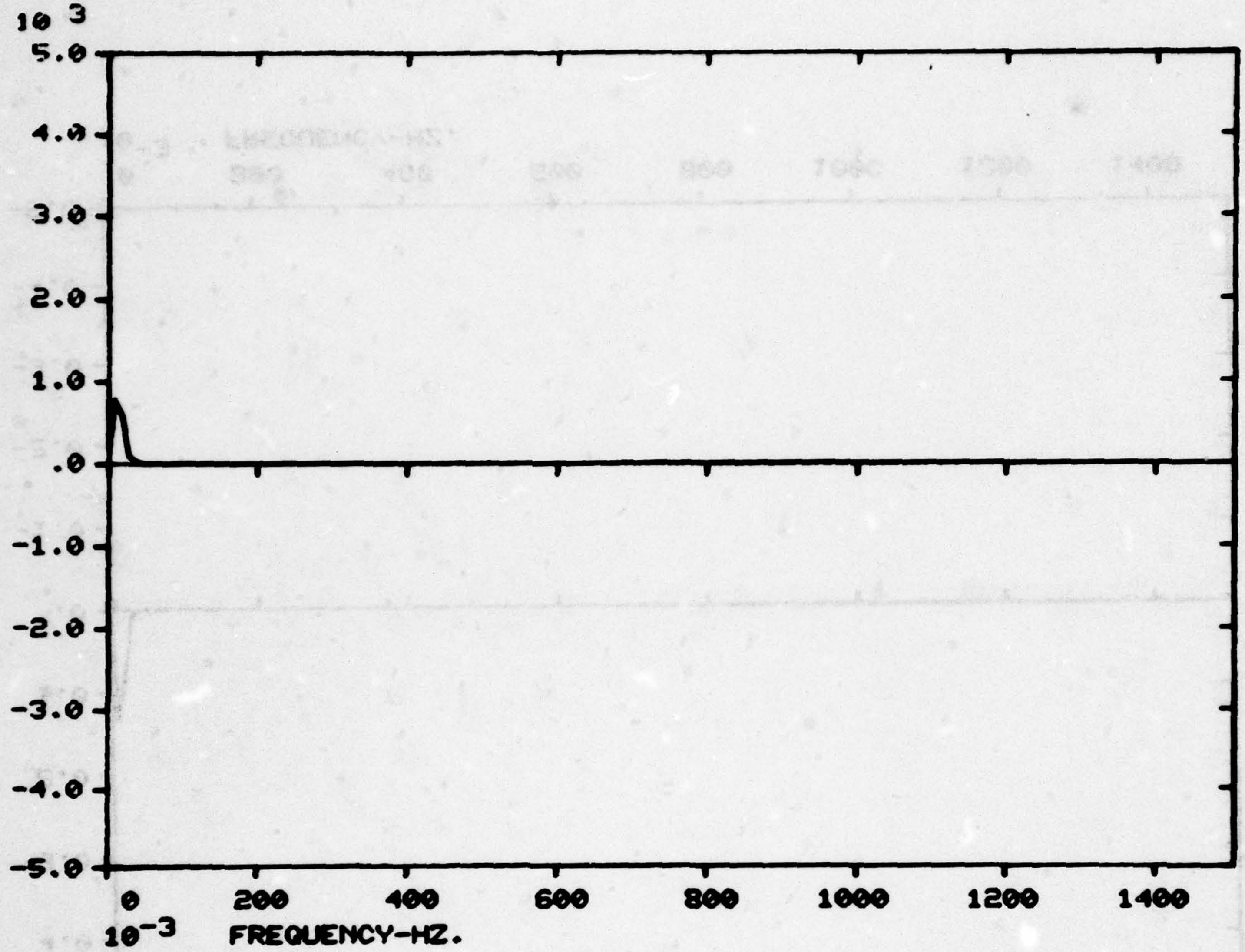


Figure B-93. Kollsman 20K PSD, Scene 7

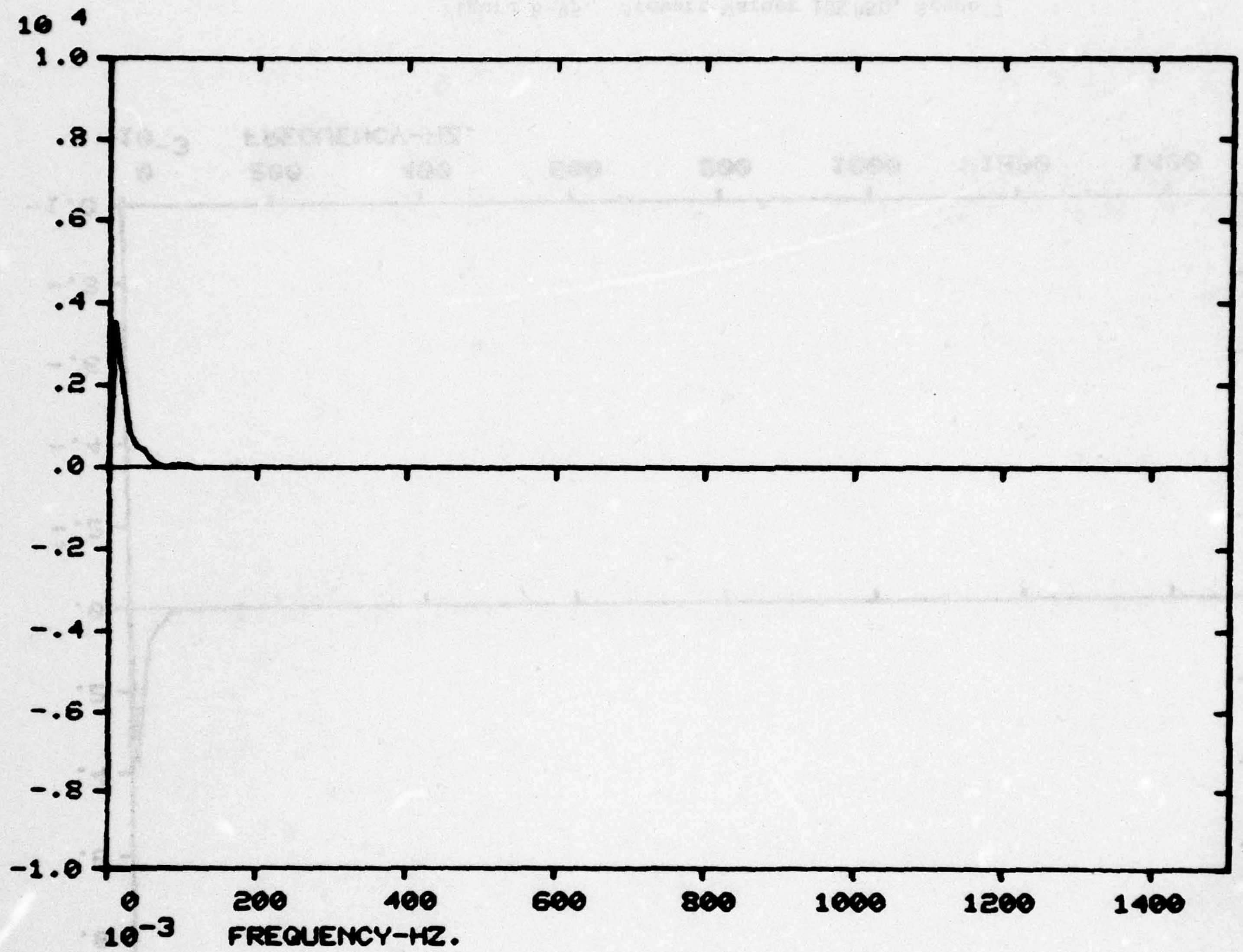


Figure B-94. Honeywell 10K PSD, Scene 7

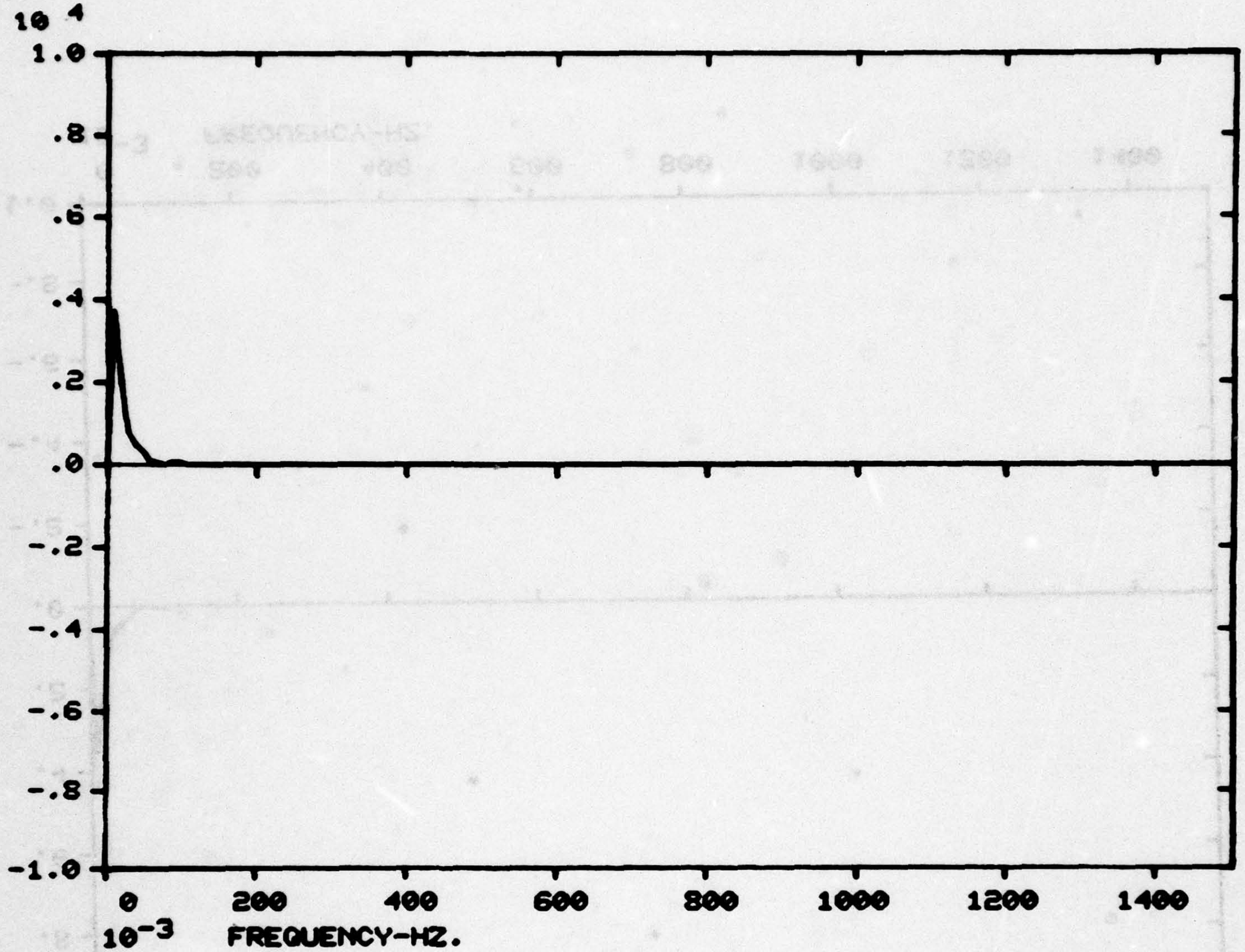


Figure B-95. Stewart-Warner 10KPSD, Scene 7

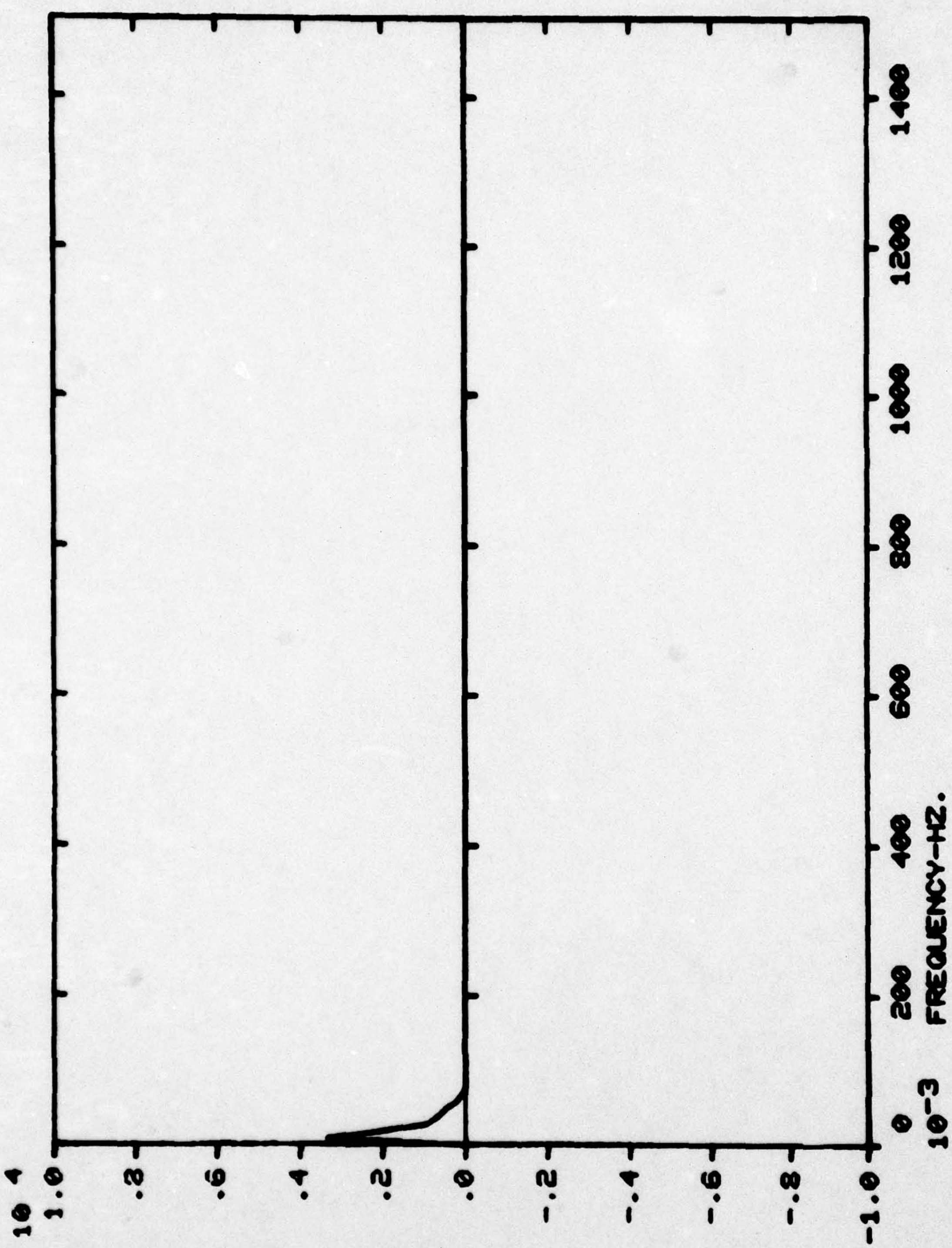


Figure B-96. Kollsman 10K PSD, Scene 7

*U.S.Government Printing Office: 1979 — 657-002/440